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Authors submitting articles to the *Egyptian Journal of Neurosurgery* do not have to be members of the E.S.N.S.. The Journal welcomes original articles from authors with diverse clinical and scientific interests provided that the article has a relevance to the science and practice of neurosurgery, in its widest sense. Articles are submitted for publication on the understanding that they have not been submitted simultaneously or published in another journal. Articles are subjected to peer review and the editor reserves the right to make the final decision regarding publication and to make literary amendments as deemed necessary. The following types of articles would be considered for publication:

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- Type or print out the manuscript on white A4 paper, with margins of at least 25mm (1 inch).
- Type or print on only one side of the paper.
- Please number the pages consecutively, beginning with the title page.
- The article is to be divided into:

  Page 1: Covering letter
  A covering letter signed by all authors stating that all authors have seen and approved the manuscript and are fully conversant with its contents. They should transfer copyright of their manuscript to the journal.

  Page 2: Title page
  Title page should carry:
  1. The title of the article, which should be concise (not more than 90 characters), but specific and informative.
  2. Names of authors and coauthors, and academic degrees.
  3. Affiliation for each author (department, hospital, or academic institution) to which the work should be attributed.
  4. Name and full address (including phone, fax number, and e-mail address) of the author with whom correspondence will be made regarding the processing and proofing of the manuscripts as well as handling of reprints.
  5. A short running title of no more than 40 characters to be used in the header of the article.

Page 3:

**Abstract** of 200-300 words. The abstract should be structured and concisely give the main aspects and features under the following clearly labeled sections: *Background, Objective(s), patients (material) and methods, results, and conclusion*.

**Key words:** 3-6 key words for indexing should be given on the same page of the abstract.

Page 4 . . . .: Manuscript compose of:

**Introduction:** State the purpose of the article and summarize the rationale for the study. Give only strictly pertinent references and do not include data or conclusions from the work being reported.

**Patients(material) and Methods:** Describe your selection of the experimental subjects (patients or laboratory animals, including controls). Identify the important characteristics of the subjects. Identify the methods, instrumentations (give the manufacture’s name and address in parentheses), and procedures in sufficient detail to allow other workers to reproduce the results. Identify precisely all drugs and chemicals used, including
generic name(s), dose(s), and route(s) of administration. Describe statistical methods with enough detail to enable a knowledgeable reader to access to the original data to verify the reported results. Specify any computer programs used.

**Results:** Present your results in logical sequence in the text, tables, and illustrations. Do not repeat in the text all the data in the tables or illustrations. Emphasize or summarize only important observations. Do not interpret your results in this section.

**Discussion:** Emphasize the new and important aspects of the study and the conclusions that follow from them. Relate the observations to other relevant studies.

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**Disclaimer (and/or) acknowledgments (if any):** The author(s) should mention clearly any financial support they received or financial interests they have concerning the submitted article. Acknowledgments can also be noted here.

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**Figures:** Figures should be numbered consecutively in Arabic numerals according to the order of their citation in the text. The figure number is to be followed by a brief informative description. Figure should be of high quality. Color figures are accepted with extra charge.

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**Revised manuscripts must be returned within 3 weeks of receipt; major alterations will not be accepted. Five reprints of the paper will be supplied to the corresponding author. More reprints can be provided with extra charge.**
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Dear Colleagues,

I am very happy to see our journal back to publish after a standstill for some time. It will flourish only by all our efforts and scientific contribution, something I am sure we will all share. Our Neurosurgical society was founded 37 years ago, one of the oldest in our field and we deserve a journal that speaks to the world about our continues scientific contributions. The new edition is aiming to reach to international levels and to be recognized worldwide. I wish to express my sincere thanks to Professor Ahmed Zohdi for his great and persistent effort to put back our journal to life. Special thanks to Professor Abdel Wahab Ibrahim who kept alone our electronic site and publication. We will not forget our Professor Mohamed Lotfy who carried the task of publication and editing for a long time. Finally all the best and waiting for your contributions.

Professor  Hossam El Husseiny
President of ESNS
Dear friends and colleagues, members of the Egyptian Society of Neurological Surgeons

it is my pleasure and honor to introduce to you this new issue of the Egyptian Journal of Neurosurgery the official scientific journal of our society in a new form, a lot of effort is being done by the new editorial board to pave the way for this journal towards internationality, thanks to Prof. Zohdi and his team and many thanks for Professors Zidan and Lotfy who carried the job sincerely and effortlessly throughout the past issues. A look for a new horizon for our journal should be our aim and we all should participate in making its success and publicity to reflect a real image about the neurosurgical practice in Egypt and to encourage neurosurgeons from all over the world to make their publications in it, this what we deserve as the first country to practice neurosurgery in Arab world, Middle east and Africa. Looking forward for your active input in the coming issues, I am honored again to present in this issue some aspects of my humble experience in treatment of lumbar spinal canal stenosis.

Hope you and our society all the best.

Prof Dr Sherif Ezzat, MD
2nd Vice President WFNS
President MENS
Honorary President PANS
Honorary President ESNS
Prof. of Neurosurgery
Al Azhar University
Cairo Egypt
**EDITOR’S CHOICE**

Long Term Results of Decompressive Laminectomy in Treatment of Lumbar Spinal Canal Stenosis (A Thirty Years Retrospective Study)

**Sherif Ezzat, MD**
Neurosurgical Department, Al Azhar University

**ABSTRACT**

**Background:** New minimal invasive procedure is trying to replace the old classic decompressive laminectomy. Result of the decompressive laminectomy should be well documented to compare these new procedures with it. **Objective:** To evaluate the long term results of wide decompressive laminectomy in treatment of lumbar spinal canal stenosis (LSCS).

**Patients and Methods:** 384 cases having circumferential narrowing of their lumbar spinal canal with no evidence of spondylothesis or other bone pathology operated by open wide decompressive laminectomy through the period from 1976-2006, the results of surgery is evaluated first after one year then on a regular five years interval in a retrospective study to evaluate the results according to the JOA and POLO scales and to measure the recovery rate utilizing the Hirabayashi method. **Results:** Follow up after one year revealed marked improvement in most cases (74.3%) according to the JOA scale, 73% were grade 5 according to the POLO scale and the recovery rate was excellent 74.2% on utilizing the Hirabayashi method. This improvement was maintained throughout the period of follow up. The last follow up conducted on 123 patients revealed persistent excellent recovery rate in 72.1 of them according to Hirabayashi method. **Conclusion:** In properly selected cases of LSCS open wide decompressive laminectomy has stood the test of time as a safe, simple, rapid procedure with much less incidence of complications and maintained long term patient improvement than other advocated minimally invasive surgical (MIS) techniques which still need evidence based evaluation of its results.

**Key Words:** lumbar spinal stenosis, wide decompressive laminectomy, minimally invasive procedures.

**INTRODUCTION**

Lumbar spinal stenosis is a well-known clinical, radiological, pathological and operative entity. Probably Portal of France was the first to describe that narrow lumbar spinal canals were associated with leg pain and atrophy in 1803.

One of the first descriptions of lumbar myelopathy may have been that of Sachs and Frankel in 1899, long before the introduction of myelography. Their patient had sacral and lumbar pain which necessitated walking bent forwards and was eventually relieved by two level laminectomy.

This date 1899 is important as it points to the very long history of laminectomy as a treatment for lumbar spinal canal stenosis. Since that time till now traditional surgical treatment of acquired lumbar canal stenosis has been wide laminectomy allowing decompression of the neural structures through unroofing the canal.

The criticism directed to laminectomy in treatment of lumbar spinal stenosis is based on:

1. Local tissue trauma.
2. Possible postoperative instability.

Accordingly, many new surgical procedures have been advocated aiming primarily at less local tissue trauma and avoidance of post-operative instability. Most of these surgeries are time consuming, may fail to achieve sufficient decompression and it may minimize but not alleviate back muscle atrophy, moreover the multiplicity of these surgical approaches each with its advocates trying to impress its superiority leads to a lot of perplexion among surgeons.

There are plenty of publications comparing traditional laminectomy and the more sophisticated new techniques in treatment of lumbar spine. Having all what have been published in literature regarding treatment of lumbar spinal stenosis recently in mind, and being one of those who practiced wide decompressive laminectomy in treatment of narrow lumbar spinal canal for more than 30 years, I decided to go through my cases to reevaluate the results according to the JOA and polo scales and to measure the recovery rate utilizing the Hirabayashi method according to the following formula:

\[
\text{recovery rate} \% = \frac{\text{postoperative score} - \text{preoperative score}}{15 - \text{preoperative score}} \times 100
\]

Recovery rate was classified into one of four groups at the end of first year follow up:

- **Excellent:** more than 75%
- **Good:** 50–74%
- **Fair:** 25–49%
- **Poor:** 24% or less

Aiming at evaluating the long term results of wide decompressive laminectomy in treatment of lumbar spinal canal stenosis (LSCS)
MATERIAL & METHODS

384 cases; 253 males (65.9%) and 131 females (34.1%) were selected for this retrospective study. Their ages ranged from 45-72 years (median 58.6). All the cases were fulfilling the clinical and radiological criteria of lumbar spinal stenosis. All cases are having circumferential narrowing of the canal. Cases having other bone pathology or any degree of spondylolisthesis were excluded.

The preoperative evaluation included radiological assessment and evaluation of the symptoms and signs according to the JOA scale. Surgery was performed to all patients under general anaesthesia and the patients were put in the prone position. Levels affected were confirmed by fluoroscopy. Care was taken during the subperiosteal muscle separation in an attempt to minimize muscle damage and to lessen blood loss. Wide decompressive laminectomy, removing the hypertrophied ligamentum flavum together with undercutting of the hypertrophied articular facets without disturbing the integrity of the facet joints and foraminotomy was done in all cases. The decompressive procedure is continued till a nicely decompressed pulsating dura is seen. Post operative early ambulation same day of surgery was routinely encouraged.

RESULTS

Two levels of the spine needed decompression in 230 cases (60%), while one level needed decompression in 98 cases (25.5%), and three levels were decompressed in 56 cases (14.5%). The commonest level affected was L4-L5 it was affected in 315 cases (82%) while the least was L1-L2 which was affected in 11 cases (2.9%) operative and early post operative complications included: dural tears managed by direct suture or covered by oxycell and a piece of crushed muscle if inaccessible in 17 cases (4.4%), and superficial wound infection managed by repeated dressing and antibiotics in 23 cases (6%).

Follow up evaluation of all cases after one year when applied to the JOA scale assessment revealed varying degrees of improvement being marked in most cases, (74.2%).

Rating according to the polo scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>73%</td>
<td>5</td>
</tr>
<tr>
<td>18%</td>
<td>4</td>
</tr>
<tr>
<td>7%</td>
<td>3</td>
</tr>
<tr>
<td>2%</td>
<td>2</td>
</tr>
<tr>
<td>0%</td>
<td>1</td>
</tr>
</tbody>
</table>

On measuring the recovery rate utilizing the Hirabayashi method, the recovery rate was found to be:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Recovery Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>74.2%</td>
</tr>
<tr>
<td>good</td>
<td>16.7%</td>
</tr>
<tr>
<td>fair</td>
<td>8.3%</td>
</tr>
<tr>
<td>poor</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

The follow-up evaluation was repeated every five years, of course on a diminishing number of cases due to death of some or lost tracking of others.

123 operated patients (32.0%) were included in the last follow-up.

Results of last evaluation according to Hirabayashi method were:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>72.1%</td>
</tr>
<tr>
<td>Good</td>
<td>15.4%</td>
</tr>
<tr>
<td>Fair</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

Not a single case of post operative instability was detected in this series till the last follow-up.

DISCUSSION

Lumbar spinal stenosis refers to a diversity of conditions that decrease the total area of the spinal canal, lateral recess, or neural foramina. Lumbar stenosis is a common disorder that may present in isolation, with or without disc bulge or herniation, or can be associated with degenerative spondylolisthesis or scoliosis. Symptomatic lumbar spinal stenosis is characterized by neurogenic claudication and/or lumbar or sacral radiculopathy. 60% to 80% of properly selected patients have a satisfactory symptomatic improvement with surgical treatment (Binder et al.)

Though portal of France 1803 was probably the first to describe the relation between narrowing of the canal and leg pain and atrophy, and the work of Sachs and Frankel 1899 who performed two level laminectomy to relieve the leg pain of a patient which necessitated him to walk bent forward, it was Verbiest 1954 who fully described the pathology, radiology, clinical picture and treatment of lumbar spinal canal stenosis.

Arnoldi 1976 classified lumbar spinal canal stenosis etiologically into: degenerative, developmental, combined spondylotic and spondylolisthetic, iatrogenic and post traumatic. Wide laminectomy allowing decompression of the neural structures through unroofing of the canal, remained the main milestone of surgical treatment of lscs, however criticism directed to this technique is largely based on local tissue trauma and possible post operative instability.

Gerald et al. 1994 mentioned that outcome after laminectomy for lumbar spinal canal stenosis was found less favorable than previously reported and that controlled trials are needed to determine efficiency of lumbar fusion as an adjunct to decompressive laminectomy.

On the other hand turner et.al 1997 found that for several low bac disorders no advantages has been demonstrated for fusion over surgery without fusion and complications of fusion are common. Nancy e. Epesten 1997 found that 90-95% of congenital or
acquired variants may be adequately managed by means of decompression without fusion.

In a more recent study son’s et al, 2013 comparing decompression alone and with fixation in a 5 years retrospective comparative study concluded that decompressive laminectomy alone achieves good outcomes in patients with two level or more lscs, associated with advanced age, poor general condition or osteoporosis.

During the past four decades with the introduction and progress of minimally invasive surgery (mis) many new surgical techniques have been advocated aiming at decreasing local tissue trauma and avoiding post operative instability, among these techniques are the following: open door laminotomy, partial undercutting facetectomy, microdecompression, unilateral laminectomy for bilateral decompression, distraction laminoplasty, port hole laminotomy, spinous process implantation and lumbar spinous process split.

Kreiner ds, et al 2013 published results of a study designed as an evidence- based review of the available data to determine if the literature supports use of minimally invasive lumbar decompression (mild®) procedures to reduce pain and improve function in patients with symptomatic degenerative lscs ; he came to the conclusion that the current body of evidence addressing mild®is of low quality . High quality studies that are independent of industry funding and provide categorical data are needed to clarify the properties of patients who benefit from mild® and the degree to which these patients benefit . Additional data at up to two years are needed to determine the overall utility of the procedure.

Another comparative study done by Anget’s al 2013 came to the conclusion that, compared with an open approach, mis lumbar laminectomy gave no clear advantages in longer term functional or pain scores. The mis group also had patients with an inadvertent durotomies and reoperation within two years in any lumbar decompressive surgery. The purposed advantages of amis approach should be carefully weighed against potential complications. For a relatively simple surgery such as laminectomy, the open approach remains a safe and straightforward operation.

Mayer hm,2001 mentioned that a vast number of minimally invasive or so called semi-invasive procedures have been published in the last three decades but evidence based data on efficiency and benefit of most of these techniques is still lacking.

Ivanov 2007 demonstrated considerable increase in stresses at both the pars interarticularis and the inferior facet after limited decompressions, especially in extension and rotation to the contralateral side.

So besides the fact that most of these surgeries are time consuming, may fail to achieve sufficient decompression and the fact that it may minimize but not alleviate back muscle atrophy especially if multiple levels are affected, another important issue is the radiation hazard to both the patient and medical team.


In this retrospective study based on follow up of 384 cases of clinically and radiologically proven lscs , all of them having circumferential narrowing of the canal, cases having other bone pathology or any degree of spondylolisthesis were excluded. These cases were operated upon over 30 years 1976-2006 and were timely followed up one year after surgery then every 5 years till the time of this publication .the results were evaluated according to the JOA and polo scales and the recovery rate was measured utilizing the Hirabayashi method.

The procedure done for all cases is wide decompressive laminectomy with under cutting of the articular facets without disturbing the integrity of the articular facet joints, in addition to foraminotomy. The decompression is carried out till a nicely decompressed pulsating dura is seen , to achieve this , laminectomy may sometimes be extended beyond what appears radiologically as the affected segment(s) , doing so , definitely lessens the possibility of late recurrence of symptoms which mostly happens due to progressive narrowing of the missed potentially narrow adjacent segment(s).

The safety of this technique is reflected by the few number of operative and postoperative complications, there were 7 cases of dural tears (1.8%) and 23 cases of superficial wound infection (6%), no nerve root injuries, post operative neurological deterioration or instability was encountered in this series.

Patient improvement after one year when applied to the JOA scale assessment revealed marked improvement in most cases (74.3%), while according to the polo scale 73% of patients are rated grade 5, and the recovery rate measured by the Hirabayashi method in 74.2% of patients is excellent.

This early improvement was maintained throughout the regular follow up done every 5 years. The last follow up done on 123 patients (32%) having their surgeries done 5-30 years ago revealed excellent recovery rate in 72.1% according to Hirabayashi method.

The results achieved in this long term study supports the view that open wide decompressive laminectomy is a safe rapid method in treatment of properly selected cases of lscs allowing dealing with all elements sharing in the narrowing of the canal with...
much less incidence of complications and long term good results with no hazard of radiation exposure

CONCLUSION

Open wide decompressive laminectomy in treatment of lumbar spinal canal stenosis is ideal as it is safe, simple, rapid procedure that stood the test of time. It allows the surgeon to nicely decompress all the neural elements inside the stenosed canal effectively and safely with a low incidence of complications and a long term good maintained recovery.

Other advocated minimally invasive surgical techniques are more time consuming, its ability to deal fully with all the stenosing elements inside the canal is questionable, the local tissue trauma is not eliminated especially in two or more level stenosis, over and above the radiation hazard to the patient and the medical team has to be assessed. The long term results are lacking and more evidence based studies are needed.

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**Original Article**

**Introduction of Vaginal Probe for Intraoperative Ultrasound of Intraaxial Brain Lesions**

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**ABSTRACT**

**Background:** It is generally accepted that in the management of brain lesions the optimal results may be obtained when maximal surgical resection is achieved with minimal disturbance of neurological function. The MR/CT modality is expensive and available only in few centers. Ultrasonography (US) can offer real-time imaging; also reported to be successful in assisting tumor localization, resection control. Its particular relevance for neurosurgery involves both its ability to provide the surgeon with immediate feedback. IOUS vaginal ultrasound probe is available in most of the medical centers and it allows with its small finger probe its use in limited space, which encouraged us to conduct this study especially that it could be a good neuronavigation substitute in developing countries. **Objective:** To evaluate the suitability of vaginal ultrasound as a substitute to neuronavigation in developing countries. **Patients and Methods:** Included 21 patients, contrasted CT axial 5mm slice interval cuts were used. Intraoperative ultrasound was performed with GE device 6.5-MHz, vaginal probe. Data collection and statistical analysis targeting the recorded volumes of the pre-operative CT and pre-opened dura IOUS and comparing the end of the procedure IOUS and the post-operative CT images. Paired t- test was used to compare the volume means difference. **Results:** Pre resection tumor volume calculated revealed a Mean volume of 28.5 cc. Post resection an IOUS volume was also calculated revealed Mean volume 0.376 cc. The mean difference between post resection IOUS and postoperative CT was 0.072. **Conclusion:** Vaginal probe IOUS was a reliable method to detect almost same tumors volumes calculated by pre and post operative enhanced CT scan.

**Key words:** IOUS, brain tumors, gliomas, vaginal ultrasound probe

**INTRODUCTION**

Intraaxial Brain tumors are often rapidly fatal, particularly when they are malignant. The reported incidence of primary and metastatic brain tumors combined is 16.7 per 100,000 persons. Uncontrolled and retrospective studies of surgical series have confirmed that the most effective management of malignant intracranial tumors, whether primary or metastatic, is surgical resection followed by adjuvant irradiation and chemotherapy.

It is generally accepted that in the management of brain lesions the optimal results may be obtained when maximal surgical resection is achieved with minimal disturbance of neurological function. To achieve this goal, accurate localization and precise delineation of tumor margins are required.

Preoperative computerized tomography (CT) and magnetic resonance (MR) imaging readily identify the morphological features of tumors, but neither one sufficiently depicts the margins of a solid tumor, infiltrating tumor cells, peritumoral edema, or normal brain adjacent to tumor.

However, the use of intraoperative CT or MR during brain tumor resection is not always feasible especially in developing countries. Although intraoperative MR (iMR) imaging has been proven to be more precise than 2D ultrasound, especially in detecting small tumor remnants, this modality is expensive and available only in few centers. These factors likely contribute to the lack of their routine use.

Frame-based and frameless stereotactic preoperative data-based techniques, also called neuronavigation systems, are used to help surgeons plan the site of craniotomy and identify critical structures, but these systems have inherent problems related to loss of accuracy resulting from unpredictable distortions, shifts and deformations after craniotomy and tissue removal.

Intraoperative MRI (iMRI) and intraoperative CT (iCT) seem to address this limitation. Unfortunately, iMRI and iCT require long image acquisition times, immense economic investments, special surgical equipment (iMRI), and special workspaces. Putting also in mind the ionizing radiation associated with CT and MRI.

Ultrasonography (US) has been employed as a guide and diagnostic tool in neurosurgery practice in its present form since 1980s. As US can offer real-time imaging, intraoperative ultrasound (IOUS) has been frequently reported to be successful in assisting tumor localization, resection control, image-guided biopsies, vascular imaging, and spinal procedures. IOUS is an affordable, simple, and time-saving intraoperative...
tool that might be a valuable neuroimaging technique of choice to shorten operation time, avoid radiation, and improve resection control. Also the US is available in most of the centers with no extra expenses and differentiates solid tissue from liquefaction or cyst. Its particular relevance for neurosurgery involves both its ability to provide the surgeon with immediate feedback and it helps in achieving maximum resection of the tumor. It seems that the active use of IOUS may be associated from liquefaction or cyst. Its particular relevance for neurosurgery involves both its ability to provide the surgeon with immediate feedback and it helps in achieving maximum resection of the tumor. It seems that the active use of IOUS may be associated with brain tumor enrolled between January 1, 2011, and July 30, 2013. All of patients (Table 1) had comprehensive physical, neurological, laboratory and radiological investigations including contrast enhancing brain MRI, in addition to the contrast enhancing CT brain and axial 5mm slice interval cuts was used to record X and Y dimension in the maximum diameter picture, and the Z dimension calculated by the number of slides in which the mass appear multiplied by slice interval.

Tumor volumes were estimated by the geometrical formula for the volume (V) of a porlate ellipsoid based on the largest transverse (A), anteroposterior (B), and coronal diameters (C):

\[ V = \frac{4}{3} \times \pi \times A \times B \times C \]

or

\[ V = 0.523 \times A \times B \times C \] (in cu cm).

The number obtained was regarded as the best estimate of tumor volume. The tumor have been approximated to ellipsoids and their volumes were calculated as the product of three perpendicular diameters divided by 2:

\[ V = \frac{d_1 \times d_2 \times d_3}{2} \]

Where d1, d2, d3 is the tumor diameter in centimeter.

**Ultrasound station**

Intraoperative ultrasound was performed with GE device (General Electric, USA) A 6.5-MHz intraoperative vaginal probe was applied. The transducer and cord were placed in a transparent plastic surgical sterile sheath secured at the scan head by a sterile rubber band using the available sterile surgical hand gloves filled with sterile lubricant. For proper transmission of the acoustic beam between the sheathed scan head and the operative interface, irrigation of the operative field with sterile saline is generous. Fig. (1).

**Intraoperative scanning**

After a craniotomy was performed, we interpreted the data. First, the sheathed scan head was placed on the surface of the dura mater for scanning before opening the dura where we identified the site and size of the lesion before any brain shift, which could result from CSF drainage. We identified the borders through a tedious move between the mass/brain interface.

Before dural opening; the distance from the tumor to the dura and the location and size of the tumor were measured and compared with preoperative available contrasted CT images. Dural opening then follows, and the scan head is placed directly to the surface of the brain tissue for further scanning, during which continuous irrigation with saline was performed.

Localization of the tumor, its consistency and borders with normal brain were studied, followed by a colored mode scanning to identify any close vascular structures, then returning back to B-mode scan to look for any relation of the tumor to nearby anatomical landmarks, like: the ventricles, the tent, and the cerebral aqueduct.

After collecting all these data, we started tumor excision from the nearest safe part, targeting any anatomical limbus as a lighthouse Fig. (2). As the tumor debulking proceeds, repeated scanning is performed to serve the delineation of hematoma from the residual mass.

The contrasted CT axial 5mm slice interval cuts was used to record X and Y dimension in the maximum diameter picture, and the Z dimension calculated by the number of slides in which the mass appear multiplied by slice interval.

**Patients & Methods**

Prospective study of intraoperative ultrasound on 21 patients (male: female=10:11, age range 2–74 years) with brain tumor enrolled between January 1, 2011, and July 30, 2013. All of patients (Table 1) had comprehensive physical, neurological, laboratory and radiological investigations including contrast enhancing brain MRI, in addition to the contrast enhancing CT brain; the main benefit of the CT was the feasibility of pre- and post-operative comparison.

We stamped the case as gross total resection (GTR) when no residual is recognized in the post-operative contrast enhancing CT brain and stamped as subtotal resection (STR) when a 20% residual is recognized in the post-operative CT. We adopt the contrast CT brain
evaluate the tumor residue and its new relation to surrounding structures. After assuming total excision, another scan is performed after filling the tumor cavity with sterile saline to get an idea about the size of the created cavity and compare it to the original tumor size, and any tumor residue was looked for and excised.

The vaginal probe was applied and x, y dimensions were recorded then a 90 degree twist for the tip of the probe in any direction to record the coronal dimension (z-dimension)

**Statistical Analysis**

Data collection and statistical analysis only targeted the efficiency of the adopted vaginal probe through a simple comparison between the recorded volumes of the pre-operative CT and pre-opened dura IOUS and comparing the end of the procedure IOUS and the post-operative CT images. Paired t-test was used to compare the volume means difference.

**RESULTS**

Comparing the results of immediate post-operative CT to those from the IOUS, there was no popping up missed tumor residue that could have been resected.

**Tumor localization:**

Vaginal US probe was helpful in localization of brain tumors regardless of their pathology we included different pathology in our study table 1. Tumor borders were well defined by IOUS and it was easily differentiated from normal brain tissue in all of our cases.

Tumor volume means difference from CT and IOUS: (table 2 & 3)

Prereossection tumor volume calculation using IOUS was done and revealed a Mean volume of 28.5 cc with SD 24.421 cc and SEM 5.329. Tumor volumes was also calculated in preoperative CT and revealed Mean volume 27.643 cc with SD 23.734 and SEM 5.179. The mean difference between prereossection IOUS and preoperative CT was 0.87 cc with P= 0.91, 95% CI= -14.15 to 15.9.

Post resection IOUS volumes was also calculated and revealed Mean volume 0.376 cc with SD 1.1 and SEM 0.24.Tumors volumes calculated in post operative CT revealed mean volume 0.448 with SD 1.579 and SEM 0.345. The mean difference between post resection IOUS and postoperative CT was 0.072 with P=0.86, 95% CI= -0.92139 to 0.77739.

Thus, there is no statistical significant difference in volumes calculated by IOUS and that calculated by CT either for prereossection or post resection. That is to say, in our study vaginal probe IOUS was a reliable method to detect almost same tumors volumes calculated by pre and post operative enhanced CT scan.

**Extent of resection:**

In our series vaginal probe IOUS was helpful to have a gross total resection in 12 cases, Fig.(3). In 9 cases IOUS detected tumor residual compared to post operative CT with a mean residual volume 0.4 cc. It was the decision of the surgeon to leave the residue to avoid injury to eloquent brain area or nearby vessel. There is a noticeable a stamp of GTR with the high grade lesions; particularly high grade astrocytoma and metastasis, yet it is not a statistically significant remark.

**Table 1: Degree of resection, site and pathology**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age (years)</th>
<th>Degree of resection</th>
<th>Diagnosis</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>14</td>
<td>GTR</td>
<td>PXA</td>
<td>Left parietal</td>
</tr>
<tr>
<td>Case 2</td>
<td>22</td>
<td>GTR</td>
<td>Oligodendroglioma</td>
<td>Left parietal</td>
</tr>
<tr>
<td>Case 3</td>
<td>2</td>
<td>STR</td>
<td>Pilocytic astrocytoma</td>
<td>Right temporal lobe</td>
</tr>
<tr>
<td>Case 4</td>
<td>34</td>
<td>STR</td>
<td>Fibrillary astrocytoma</td>
<td>Right temporal</td>
</tr>
<tr>
<td>Case 5</td>
<td>28</td>
<td>GTR</td>
<td>Gemistocytic astrocytoma</td>
<td>Right parietal</td>
</tr>
<tr>
<td>Case 6</td>
<td>33</td>
<td>STR</td>
<td>Protoplasmic astrocytoma</td>
<td>Right temporal</td>
</tr>
<tr>
<td>Case 7</td>
<td>32</td>
<td>GTR</td>
<td>Metastatic</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 8</td>
<td>66</td>
<td>GTR</td>
<td>GBM</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 9</td>
<td>6</td>
<td>STR</td>
<td>Medulloblastoma</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 10</td>
<td>7</td>
<td>GTR</td>
<td>Immature teratoma</td>
<td>Suprasellar</td>
</tr>
<tr>
<td>Case 11</td>
<td>8</td>
<td>STR</td>
<td>Pilocytic astrocytoma</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 12</td>
<td>9</td>
<td>GTR</td>
<td>Pilocytic astrocytoma</td>
<td>Left parietal</td>
</tr>
<tr>
<td>Case 13</td>
<td>19</td>
<td>STR</td>
<td>Fibrillary astrocytoma</td>
<td>Right temporal</td>
</tr>
<tr>
<td>Case 14</td>
<td>14</td>
<td>STR</td>
<td>Metastatic</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 15</td>
<td>39</td>
<td>STR</td>
<td>Ependymoma</td>
<td>Posterior fossa</td>
</tr>
<tr>
<td>Case 16</td>
<td>6</td>
<td>GTR</td>
<td>Anaplastic astrocytoma</td>
<td>Right frontal</td>
</tr>
<tr>
<td>Case 17</td>
<td>13</td>
<td>GTR</td>
<td>SEGA</td>
<td>Intraventricular</td>
</tr>
<tr>
<td>Case 18</td>
<td>57</td>
<td>STR</td>
<td>GBM</td>
<td>Left parietal lobe</td>
</tr>
<tr>
<td>Case 19</td>
<td>39</td>
<td>STR</td>
<td>Subependimoma</td>
<td>Intraventricular</td>
</tr>
<tr>
<td>Case 20</td>
<td>43</td>
<td>STR</td>
<td>Metastatic</td>
<td>Left parietal lobe</td>
</tr>
<tr>
<td>Case 21</td>
<td>51</td>
<td>GTR</td>
<td>Metastatic</td>
<td>Posterior fossa</td>
</tr>
</tbody>
</table>
Table 2: Pre-resection dimensions and volumes of IOUS compared to CT

<table>
<thead>
<tr>
<th>Patients</th>
<th>Diagnosis</th>
<th>Pre resection images</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VP IOUS</td>
<td></td>
<td>Zc</td>
</tr>
<tr>
<td></td>
<td>Volume cc</td>
<td>Zs Ys Xs</td>
<td>Volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zc Yc Xc</td>
</tr>
<tr>
<td>Case 1</td>
<td>PXA</td>
<td>37.2 48 47 33</td>
<td>34.9 47 45 33</td>
</tr>
<tr>
<td>Case 2</td>
<td>oligodendroglioma</td>
<td>82.1 70 69 34</td>
<td>76.2 66 66 35</td>
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<tr>
<td>Case 3</td>
<td>Pilocytic astrocytoma</td>
<td>32.8 41 40 40</td>
<td>29.6 39 38 40</td>
</tr>
<tr>
<td>Case 4</td>
<td>Fibrillary astrocytoma</td>
<td>48.4 39 31 41</td>
<td>19.4 33 31 38</td>
</tr>
<tr>
<td>Case 5</td>
<td>Gemistocytic astrocytoma</td>
<td>51.3 50 50 41</td>
<td>54.4 52 51 41</td>
</tr>
<tr>
<td>Case 6</td>
<td>Protoplasmic astrocytoma</td>
<td>52.3 22 22 22</td>
<td>4.4 22 20 20</td>
</tr>
<tr>
<td>Case 7</td>
<td>Metastatic</td>
<td>33.6 42 40 40</td>
<td>29.6 38 39 40</td>
</tr>
<tr>
<td>Case 8</td>
<td>GBM</td>
<td>7.2 21 23 30</td>
<td>7.2 22 21 31</td>
</tr>
<tr>
<td>Case 9</td>
<td>Medulloblastoma</td>
<td>16.7 33 39 26</td>
<td>18.5 38 36 27</td>
</tr>
<tr>
<td>Case 10</td>
<td>Immature teratoma</td>
<td>5.8 23 25 20</td>
<td>6.8 25 26 21</td>
</tr>
<tr>
<td>Case 11</td>
<td>Pilocytic astrocytoma</td>
<td>7.0 27 26 20</td>
<td>6.4 27 25 19</td>
</tr>
<tr>
<td>Case 12</td>
<td>Pilocytic astrocytoma</td>
<td>54.1 44 41 60</td>
<td>53.3 43 42 59</td>
</tr>
<tr>
<td>Case 13</td>
<td>Fibrillary astrocytoma</td>
<td>7.4 25 19 31</td>
<td>7.6 22 21 33</td>
</tr>
<tr>
<td>Case 14</td>
<td>Metastatic</td>
<td>11.6 32 33 22</td>
<td>12.3 34 33 22</td>
</tr>
<tr>
<td>Case 15</td>
<td>Ependymoma</td>
<td>4.0 21 20 19</td>
<td>4.2 22 20 19</td>
</tr>
<tr>
<td>Case 16</td>
<td>Anaplastic astrocytoma</td>
<td>57.2 52 50 44</td>
<td>58.3 52 51 44</td>
</tr>
<tr>
<td>Case 17</td>
<td>SEGA</td>
<td>9.9 32 31 20</td>
<td>8.7 29 30 20</td>
</tr>
<tr>
<td>Case 18</td>
<td>GBM</td>
<td>83.0 56 57 52</td>
<td>81.0 57 58 49</td>
</tr>
<tr>
<td>Case 19</td>
<td>subependimoma</td>
<td>28.5 32 39 39</td>
<td>28.4 39 37 39</td>
</tr>
<tr>
<td>Case 20</td>
<td>Metastatic</td>
<td>20.5 31 30 44</td>
<td>23.2 32 33 44</td>
</tr>
<tr>
<td>Case 21</td>
<td>Metastatic</td>
<td>18.4 35 34 31</td>
<td>16.4 32 33 31</td>
</tr>
</tbody>
</table>

CT = computed tomography, VP IOUS = vaginal probe intraoperative ultrasound, X= the x-dimension in mm, Y= the Y dimension in mm, Z= the Z dimension in mm PXA = pleomorphic xanthoastrocytoma, GBM = glioblastoma multiform, SEGA = subependimal giant cell astrocytoma

Table 3: Post-resection dimensions and volumes of IOUS compared to CT

<table>
<thead>
<tr>
<th>Patients</th>
<th>Diagnosis</th>
<th>Post resection images</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VP IOUS</td>
<td></td>
<td>Zc</td>
</tr>
<tr>
<td></td>
<td>Volume cc</td>
<td>Zs Ys Xs</td>
<td>Volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zc Yc Xc</td>
</tr>
<tr>
<td>Case 1</td>
<td>PXA</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 2</td>
<td>oligodendroglioma</td>
<td>0.0 0 0 0</td>
<td>0.1 5 10 5</td>
</tr>
<tr>
<td>Case 3</td>
<td>Pilocytic astrocytoma</td>
<td>0.1 5 5 5</td>
<td>0.1 7 5 6</td>
</tr>
<tr>
<td>Case 4</td>
<td>Fibrillary astrocytoma</td>
<td>0.1 10 6 4</td>
<td>0.0 5 0 0</td>
</tr>
<tr>
<td>Case 5</td>
<td>Gemistocytic astrocytoma</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 6</td>
<td>Protoplasmic astrocytoma</td>
<td>0.2 3 13 10</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 7</td>
<td>Metastatic</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 8</td>
<td>GBM</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 9</td>
<td>Medulloblastoma</td>
<td>0.7 13 5 22</td>
<td>0.2 9 11 5</td>
</tr>
<tr>
<td>Case 10</td>
<td>Immature teratoma</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 11</td>
<td>Pilocytic astrocytoma</td>
<td>0.5 20 10 5</td>
<td>0.6 10 10 12</td>
</tr>
<tr>
<td>Case 12</td>
<td>Pilocytic astrocytoma</td>
<td>0.0 0 0 0</td>
<td>0.1 10 5 5</td>
</tr>
<tr>
<td>Case 13</td>
<td>Fibrillary astrocytoma</td>
<td>0.1 6 5 9</td>
<td>0.5 10 9 11</td>
</tr>
<tr>
<td>Case 14</td>
<td>Metastatic</td>
<td>0.5 6 10 15</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 15</td>
<td>Ependymoma</td>
<td>0.2 7 6 10</td>
<td>0.2 6 5 10</td>
</tr>
<tr>
<td>Case 16</td>
<td>Anaplastic astrocytoma</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 17</td>
<td>SEGA</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
<tr>
<td>Case 18</td>
<td>GBM</td>
<td>0.1 6 5 5</td>
<td>0.1 10 5 5</td>
</tr>
<tr>
<td>Case 19</td>
<td>subependimoma</td>
<td>5.1 21 22 22</td>
<td>7.3 23 22 29</td>
</tr>
<tr>
<td>Case 20</td>
<td>Metastatic</td>
<td>0.3 9 8 7</td>
<td>0.2 6 8 7</td>
</tr>
<tr>
<td>Case 21</td>
<td>Metastatic</td>
<td>0.0 0 0 0</td>
<td>0.0 0 0 0</td>
</tr>
</tbody>
</table>

CT = computed tomography, VP IOUS = vaginal probe intraoperative ultrasound, X= the x-dimension in mm, Y= the Y dimension in mm, Z= the Z dimension in mm PXA = pleomorphic xanthoastrocytoma, GBM = glioblastoma multiform, SEGA = subependimal giant cell astrocytoma
DISCUSSION

The efficacy of the vaginal probe IOUS in localizing tumors, defining tumor borders, and assessing the extent of resection was determined in primary glioma, germ cell tumor, embryonal tumor and metastatic tumors.

Many studies have demonstrated the reliability of intraoperative ultrasound since the 1980s. In our series, we found reliable tumor localization in all 21 cases without any obstacles confirming the data of the literature. Tumor localization by intraoperative ultrasound reaches 100% independent of the histopathological diagnoses. Intraoperative conventional ultrasound was useful in the determination of tumor location, its most superficial portion, and in the differentiation between solid tumors and cystic components. The border of the tumor and remained tumor tissue were more distinguishable from healthy brain on ultrasound during the operation which helps in identifying residual tumors after assuming total resection under microscope. Intraoperative ultrasonography (IOUS) was very useful during resection of posterior fossa tumors extending to the lateral parts of the fourth ventricle or upwards to the aqueduct. Improving differentiation of the tumor tissue from normal brain with ultrasound was demonstrated in most of cases.

In our study the entire operative field was scanned in a systematic fashion in at least two perpendicular planes before and after tumor resection. Solid tumors were found to be hyperechoic in comparison with surrounding edema or brain tissue while the cystic parts are hypoechoic or anechoic. During tumor removal, IOUS was used to guide the resection toward the echogenic margin in cases for which complete excision was the aim. After the dura was closed, ultrasound was used again to assess the extent of resection, and photographs of these images were taken.

Localization was defined as either: well localized (location of tumor was well visualized by IOUS) or poorly localized (location of the tumor was not well visualized by IOUS). The margins were considered well defined when they could be clearly visualized and separated from surrounding edema and brain tissue; moderately defined when they could be visualized by IOUS but could not be clearly separated from surrounding tissue in certain areas; and poorly defined when they could not be visualized or separated from surrounding tissue.

Samdani et al. demonstrated that iMRI neurosurgery provides additional information for resection and real-time catheter placement, which we could also confirm with the IOUS technique. To date, there are no published prospective randomized studies comparing outcomes and resection control percentages between these two intraoperative imaging modalities which we think will be needed in the future.

Although IOUS is considered to be unsuitable for differentiating between surrounding tissue and edema, we could demonstrate improvements in this regard with newly developed Ultrasound probes. In 2008, He et al. used IOUS in combination with the contrast-enhancing agent to detect intracranial tumors and to differentiate between tumor tissue and surrounding tissue. However, a pitfall of this method is that other sources other than contrast enhancing tissue can represent a tumor.

Unsgaard et al. published a benchmark review article regarding developments in reconstructed 3-D US. The authors used the intraoperative imaging system SonoWand® (Mison, Trondheim, Norway) that is a high end US platform with a supplementary navigation system. Several groups have shown that the combination of image-guided neurosurgery with 3-D US increases the diagnostic value significantly. Furthermore, Letteboer et al. demonstrated that immediate updating during the operation helps to minimize the problem of brain shift.

Our Vaginal probe is not primarily designed for neurosurgical procedures, but there is an increasing corporate interest in adapting probes for brain and tumor visualization in the future, as in recent years, all settings are digital and therefore also programmable. This possibility of individual setting adjustment leads to more customizable products. Improvements in image quality and increased pixels are inevitable. In this study, we present a prospective study of vaginal probe with intracranial lesions to verify the value of Vaginal probe IOUS (which is available in most of the centers) for additional image-guided orientation in brain surgery.

In a study of 3D IOUS, RT-3-D eliminated the reconstruction time with no further disadvantages. Intraoperative real-time 3-D ultrasound. With RT-3-D IOUS technique, achieved fast and real-time imaging of the progress of the operation during all stages of the updated operation. The resolution of real-time 3-D probe was comparable to the standard quality associated with commonly used 2-D US systems and offered the surgeon enough accuracy to
compensate for brain shift. An acquisition procedure was not necessary, as 3-D data were immediately available in a live view. Repeated intraoperative image updating was valuable and easily accomplished in all cases. The use of US system did not cause alter to the surgical plan of a short skin incision and smallest possible bone flap. There was no need for enlargement of the craniotomy or extra opening for ultrasound. In fact, such extra craniotomy for ultrasound imaging is not recommended, especially in pediatric cases\textsuperscript{10}. The RT-3-D US probe is approximately 3×2 cm in size and does not exceed even a minimal craniotomy. Extent of resection and RT-3-D IOUS\textsuperscript{28}.

In our study the vaginal probe with its small foot print 0.5×1.5 cm gave us possibility to use it in limited space areas as the posterior fossa also the convex view of the probe helped to achieve high quality images with helped to guide the extent of resection.

The extent of resection in gliomas is a prognostic factor for survival\textsuperscript{5,27} . El Beltagy et al described the role of IOUS in resection of pediatric patients\textsuperscript{6} . This group worked with a 2-D 6.5-MHz probe in conventional B-mode, and EOR was the same when comparing IOUS and immediate postoperative MRI. The authors were able to achieve a total resection rate of over 55% in their series of 25 heterogeneous pediatric pathologies. They concluded that 2-D IOUS is a useful imaging technique in defining the border between the tumor and healthy brain tissue. In addition, this technique helped the surgeon to detect tumor remnants. We reached in our study a resection rate of 58% which prove what we found in literature that IOUS help to increase extent of resection.

In our series, no radical resection in eloquent areas was done avoiding significant damage. All other current IOUS publications address this issue with a similar opinion and results\textsuperscript{3,9,24-29} . There are no reports of increased neurological deficits associated with IOUS guided radical resections. On the other hand, it is difficult to conclude that IOUS directly contributes to the preservation of neurological function. This important aid is more directly supplied by intraoperative electrophysiological monitoring, as performed with cases in eloquent regions.

Appropriate neurosurgical intervention often offers the patient with a brain tumor an improved quality of life, prolonged survival, and improved control of neurological problems, even in cases of extremely aggressive tumors. The extent of resection plays a crucial role in the degree to which these advantages can be expected. Optimum resection can be achieved when the tumor is specifically localized, the borders are clearly elucidated, and any residual tumor is readily identified. Intraoperative techniques IOUS offer the obvious advantage of determining these factors in real time\textsuperscript{18}.

CONCLUSION

We do need the intraoperative real time image. We do need the small foot plate. We do need the convenient and reliable ultrasound images.

The vaginal ultrasound probe offers same quality ultrasound images, offers an eye on the tip of your finger to achieve a safe gross total resection for intraaxial brain tumors.

REFERENCES


EVALUATION OF STEREOTACTIC RADIOSURGERY FOR CEREBELLOPONTINE ANGLE (CPA) MENINGIOMA AND SHWANNOMA AFTER MICROSURGICAL DECOMPRESSION

Hesham Anwer MD, Tarek H Elserry MD, Shaﬁc Elmolla MD, Zeiad Y. Fayed MD
Department of Neurosurgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt

ABSTRACT

Background: CPA tumors are the most common neoplasms in the posterior fossa. After microsurgical decompression, the residual parts of meningiomas and schwannomas can be treated with stereotactic radiosurgery. Objective: The aim of the study is to evaluate long–term follow up of stereotactic radiosurgery after microsurgical decompression. Patients and Methods: Our study included a total of 32 patients with CPA meningioma and schwannoma, 23 cases with vestibular schwannoma and 9 cases with meningioma, these patients were subjected to microsurgical decompression and then treated with GK (gamma knife) and were followed up for at least 2 years. Results: Postoperative improvement occurred in 100% of patients with headache and in 82.5% of patients with ataxia and the postoperative complications were 7th nerve palsy occurred in 62.5% of cases, 9.4% had bulbar manifestations 3.1% had 5th nerve affection (pain), 18.75% needed re-operation due to presence of residual parts and recurrence of symptoms. Post gamma knife improvement occurred in 75% of patients presented with ataxia, and in 33% of patients presented by 5th nerve affection, and improvement occurred in single case presented by headache, single case presented by vertigo and single case presented by bulbar symptoms. Complication after gamma knife were one case of hearing deterioration, one case needed re-surgery due to tumor regrowth, odema in one case and fits in one case. Radiologically 19 cases were less in size (59%), 9 cases retained the same size (28%) and 4 cases showed progressive increase in size (13%). Conclusion: (GKS) has achieved the goals of desired treatment in both aspects: long term tumor control and lowered morbidity.

Keywords: gamma knife, cerebello-pontine-angle, SRS, skullbase, adjuvant therapy.

INTRODUCTION

Generally speaking, for patients presenting with CPA tumors, treatment options include observation with close follow-up, operative excision and radiosurgery, or a combination of these therapies. For those tumors that are suspected to be benign, observation is a reasonable option, particularly when the patient has minimal symptoms with no life threatening symptoms and acceptable presentation for life style of the patients, especially in old age patients (older than 70 years). However, while small tumors can be treated with minimal risks, larger tumors are more difficult to treat and may cause significant post-surgical problems. Because CPA tumors are deep in location and surrounded by critical structures, conventional neurosurgical approaches are disadvantageous because of the need for significant brain retraction, poor control of the lesion and adjacent structures, and often suboptimal exposure. In 1969, the first case of vestibular schwannoma (VS) treated by (GKS) was performed by Lars Leksell at the Karolinska institute in Stockholm, Sweden. This innovative and thoughtful neurosurgeon was impressed by the high rates of morbidity and mortality that was associated with the surgical resection of VS in the fifties.

Consequently, SRS is currently the most common treatment for small to medium sized VSs, resulting in good tumor control and functional outcomes.

PATIENTS & METHODS

This is a retrospective study involving 32 patients who were subjected to microsurgery for CPA tumor in Ain Shams University followed by (GKS) in Naser Institute from June 2001 to October 2009 and were followed up for at least 2 years.

All patients were subjected to detailed medical history taking, general and neurological examination, neuroradiological assessment in the form of MRI with and without contrast and auditory investigations in the form of pure tone audiometry and Arabic speech discrimination in cases where hearing was serviceable.

All patients underwent decompression with standard retrosigmoid suboccipital approach (Janetta approach). Generally the retrosigmoid approach is a safe and reliable approach for CPA tumor decompression.

SRS Protocol: The GKS procedure was performed with the aid of the leksell model G stereotactic frame (Elekta instruments) the frame was applied after mild sedation and local anesthesia had been administrated after frame application all patient underwent MRI studies, axial and coronal T1-weighted...
image with contrast enhancement were used for dose planning.

All patients treatment were planned with gamma plan software version 9. The prescription dose used in the study was strictly confined to 12 Gy but with varying isodose lines from 35 to 55% with a median of 50% and a mean of 49.6%.

Post treatment Follow Up

Patient evaluation

First of all, the pretreatment symptoms were documented and compared subjectively by the patient post treatment state. This was followed by neurological examination of the patient, keeping in mind any signs detected in the first examination, and comparing them with the current state.

Post treatment Investigations

In all cases an MRI with and without contrast axial, sagittal and coronal cuts was performed. MRI was performed at 6, 12, 24 and 36 month intervals. The routine MR examinations included the following studies:

1. Volumetric assessment was done using the following geometrical formula for the volume (V) of a porlate ellipsoid based on the largest transverse (A), anteroposterior (B) and coronal diameters (C):

   \[ V = \frac{4}{3} \times 3.14 \times A \times B \times C \]

   but tumor dimensions measured off the MRI images were not always accurate due to the fact that the MRI was not always done to the same parameters regarding the scanning angle. So, we also assessed the tumor size in relation to the surrounding structures and the mass effect of the tumor on adjacent structures especially the brain stem, cerebellum and the effect of 4th ventricle patency and in most cases there were no actual difference in assessing tumor size.

2. Detection of changes of gadolinium enhancement in the tumors.

3. Detection of adverse radiation effects or perifocal edema surrounding the tumor

   In cases in which hearing was serviceable before treatment, an audiogram with pure tone audiometry and speech discrimination was performed.

RESULTS

In our study we had 32 cases with a CPA tumor (schwannoma or meningioma), all of them subjected to Gamma Knife Radiosurgery from June 2001 to October 2009 after they were subjected to microsurgery before this treatment. All patients were followed clinically and radiologically for at least 2 years.

We had 23 (71%) cases of Vestibular Schwannomas and 9 (29%) cases of Meningiomas. No patients were discovered to have malignant tumors.

![Figure (1): Different types of pathologies in our series](image)

While Meningiomas predominate in females (8 female and one male), Schwannomas are near equally distributed in both genders (13 female and 10 males).
Pre-operative symptoms were ataxia (23 cases) and vertigo (3 cases). Headache was the main symptom of ↑ICT (23 cases), blurring of vision occurred in 9 cases, vomiting was present in 2 cases. 5 cases of them had a VP shunt pre-operatively. Deafness was present in 27 cases (only 5 patients were having useful hearing), trigeminal pain in 4 patients, bulbar symptoms in one case and blindness was present in one case due to ↑ICT.

Post-operatively approximately, all cases with ↑ICT improved, regarding cases with ataxia 19 cases (82.5%) improved, 3 cases had moderate improvement, one case only did not improved. The 3 cases with vertigo improved. 75% of cases with trigeminal pain improved. The only case with bulbar symptoms improved.
The hallmark of post-operative complications was 7th nerve palsy (62.5%: 19 paralysis & 1 case palsy), 2 of them performed hypoglossal-facial anastomosis. 9.4% had bulbar manifestations. 3.1% suffered 5th nerve affection (pain). 18.75% needed reoperation due to incomplete resection of the tumor and recurrence of symptoms, 9.4% needed VP shunts. Other less frequent complications were tremors (1 case), nystagmus (1 case), Cerebellar speech (1 case), intra-tumoral bleeding (1 case) and hemiparesis (1 case).

![Figure (5): Post-operative complications](image)

Regarding degree of surgical removal, we graded decompression to 3 grades. Minimal decompression (removal of less than 1/3 of the tumor). Moderate decompression (removal of between 1/3 and 2/3 of the tumor). Subtotal decompression (removal of more than 2/3 of the tumor). Minimal decompression was done in 50% of cases. Moderate decompression was done in 22% of cases. Subtotal decompression was done in 28% of cases.

![Figure (6): Volume of the tumor removed surgically](image)

Before Gamma Knife treatment, main symptoms were 7th nerve paralysis (19 cases), 5th nerve palsy (3 cases), ataxia (4 cases), bulbar symptoms (1 case), headache (1 case), vertigo (1 case) and there were 27 deaf (Non-Functioning ears) cases.

![Figure (7): Main symptoms before Gamma Knife Treatment](image)

Improvement after gamma knife treatment was as follow, 75% of patients with ataxia improved and 33% of patients with 5th nerve affection improved, and also improvement occur in a single case presented by headache, single case presented by vertigo and single case presented by bulbar symptoms. No facial deterioration recorded after gamma knife treatment.
Complications after Gamma Knife treatment included: one case of hearing deterioration (SRT decreased from 30 db to 55 db in 3 years). Re-surgery & VP shunting (1 case: VP shunt inserted after 2 years from the treatment as the tumor increased in size. Decompression done after 30 months, Pathology showed no malignancy), edema (1 case), this edema resolved by steroid, fits (1 case) was controlled by medical treatment.

Radiologically, 19 cases were less in size, 9 cases retained the same size & 4 cases (13%) showed progressive increase in size.

Mean duration between Gamma Knife Treatment and failure was 24 months. 3 of the 4 cases had only radiological failure. Only one case (25%) had symptoms: persistent ataxia then, she developed hydrocephalus and VP shunt inserted then, re-operation done before Re-Treatment. No cases were proved to have malignancy. All failed cases had Gamma Knife Treatment with mean duration of follow up 6 months.

Illustrated cases

Figure (10): all T1WI post contrast; 50 years old female was complaining of occasional headache, complete left side hearing loss, blurring of vision and ataxia. VP shunt inserted. Her large left vestibular schwannoma was sub-totally removed. This 1.1 cc tumor received 12 Gy to the 40% isodense with 92% and a conformity index of 1.24. Follow up after 6 years tumor size is smaller.
Pre-operative  Post-operative  after 5 years

Figure (11): All T1WI post contrast; a 40 years old male complained of left sided complete hearing loss and headache. His left vestibular schwannoma was decompressed. He suffered from moderate facial palsy (improved by time), dry left eye. This 4.4 cc tumor received 12 Gy to the 50% isodense with 90% cover and a conformity index of 1.1. After 5 years, tumor size reduced with loss of central enhancement, with no clinical deterioration.

DISCUSSION

Our study included 32 cases with a CPA tumor (schwannoma and meningioma), all of them subjected to Gamma Knife Radiosurgery from June 2001 to October 2009 after they were subjected to microsurgery before this treatment.

No cases other than schwannoma and meningioma were treated in our study. More than two thirds of the patients had schwannomas. This agrees with the well-known prevalence of the vestibular schwannoma in this particular anatomical location, followed by the meningioma. The female to male ratio in vestibular schwannoma cases was 1.3:1. It nearly agrees with the known gender distribution ratio of vestibular schwannoma of 1:1. Female gender was dominating in meningioma cases (9:1 female to male). This agrees with the well-known domination of this tumor in females.\(^\text{17}\)

Mean age at presentation in Meningioma in our study was 41 years ranging from 25 to 50 years. This agrees with the fact of frequency of meningioma in middle age and has the highest incidence in the fifth decade. Mean age at presentation in Schwannomas in our study was 39 years ranging from 20 to 70 years which agrees with range of age in other studies.\(^\text{18}\)

Before Gamma Knife treatment, main symptoms were 7th nerve paralysis (20 cases), 5th nerve palsy (3 cases), ataxia (4 cases), bulbar symptoms (1 case), headache (1 case), and vertigo (1 case) and there were 27 deaf (5 Functioning ears) cases.

The prescription dose used in the study was strictly confined to 12 Gy, but with varying isodose lines, from 35 to 55% with a median of 50% and a mean of 49.6%. In Gamma knife radiosurgery a dose of 11–13 Gy is typically prescribed to the 50% isodose line that conforms to the tumor margin. Dose prescription for vestibular schwannomas has changed significantly over the past 10 years. A margin dose of 12–13 Gy is associated with a low complication rate and yet maintains a high rate of tumor control.\(^\text{11}\)

Risk factors for cranial nerve damage during radiosurgery are reported to be total dose, total volume, prior resection, length of cranial nerve irradiated, and the maximal dose to brain stem. However, recently 14 Gy was applied to small sized tumors, 12 Gy to medium sized tumors, and 10 Gy to large one. Now the trend is to decrease the dose to 12 Gy for small sized tumors. Despite the decreased irradiation of 12 Gy, the tumor growth suppression rate is same as before, and the complications of irradiation for auditory and facial nerves have decreased. Although proper dose selection was not established, it must not exceed 14 Gy for CPA radiosurgery.\(^\text{7}\) In our study, the treatment planning was done using high resolution with thin slices and gadolinium enhancement with 3-D reconstruction for the treatment planning. For the follow up, MR imaging with gadolinium enhancement was used. Post GKS follow up in this study revealed a hearing preservation rate of 80%, as 4 out of 5 patients maintained functional hearing after 2 years of treatment.

Hearing preservation is not correlated to the maximal radiation dose at the tumor but only to the
maximal dose at the cochlea. The purpose of developing GKRS techniques was to avoid collateral damage in healthy tissues.15

The hearing preservation rate achieved after the introduction of MRI guided dose planning was raised to 67% of the patients who had serviceable hearing before undergoing GKS8. The hearing preservation rate after radiosurgery for CPA has been reported to be in the range of 40 to 78.6%. It is not easy to simply compare the various reports on global hearing preservation because of the lack of uniformity in reporting results.5 Hempel et al. have carried out GKS on 123 patients since 1994, and achieved a tumor control rate of 96.7%; the mean impairment of hearing was 18% for 8.2 years after GKS8. Hasegawa et al. conducted a follow-up observation for a relatively long term of 135 months, applied the mean marginal dose of 14.6 Gy, and hearing preservation rate was 37%. This data was relatively lower than other previous reports.5

In our study, improvement after Gamma Knife treatment was 100% of headache cases, 75% of ataxia cases, 100% in vertigo, 33% in 5th nerve affection and 100% in bulbar symptoms.

Complications after Gamma Knife treatment included: one case of hearing deterioration (SRT decreased from 30 db to 55 db in 3 years). Re-surgery & VP shunting (1 case: VP shunt inserted after 2 years after treatment as the tumor progressed. Decompression was done after 30 months, Pathology showed no malignancy, edema (1 case), fits (1 case). No reported cases of facial nerve deterioration after gamma knife treatment.

Kondziolka et al. in 1998 reported normal facial function was preserved in 79% of the 155 patients in his study. He also reported that no patient who had a normal facial function suffered from complete facial palsy after GKS. Only some of the patients with a pre-existing deficit (grades III-V) due to previous surgical trauma to the nerve have suffered progress to complete grade VI palsy.9

Radiologically, 19 (59%) cases reduced in size, 9 (28%) cases attained the same size & 4 cases (13%) increased in size by about (20%). Most of failed cases are essentially large tumors to treatment. Mean duration between Gamma Knife Treatment and failure was 24 months. 3 of the 4 cases had only radiological failure. Only one case (25% of failed cases) had symptoms: persistent ataxia then, she developed hydrocephalus and VP shunt inserted then, re-operation done before Re-Treatment. No cases were proved to have malignancy.

According to the results of GKS for CPA tumors reported by many gamma knife centers, tumor control rate ranges from 87 to 98%.5,13,10,13,19

Treatment of large tumors remains a challenge to neurosurgeons regardless of whether they perform microsurgery or radiosurgery. The size of the tumor is critical to efficacy and safety. In a large series, a poor control rate was identified in large tumors compared to small tumors.5 In general, gamma knife radiosurgery is not a suitable treatment modality for large tumors (mean diameter greater than 3 cm) because a large tumor size increase the risk of complications compared to small tumors. Significant peri-tumoral edema invariably occurs after gamma knife treatment for large tumor (larger than 3 cm), this edema potentially cause aggravation of symptoms and clinical deterioration. To avoid these complications, a low prescribed dose is recommended for large tumors. However low marginal doses have been associated with increased rate of tumor recurrence. In our study we found that the tumor size is very important in the success or failure of the treatment with gamma knife large tumor showed failure in treatment more than smaller one, the failed cases in our study were essentially large tumors to treatment regarding tumor nature cystic vs solid type we prefer microsurgery to radiosurgery for the treatment of cystic tumors because of a risk of rapid cyst expansion after radiosurgery. We found no significant difference in response to treatment between schwannoma and meningioma.

**CONCLUSION**

We recommend gamma knife radiosurgery as a planned “treatment” after microsurgery. The additional radiosurgical boost is delivered accurately to the smaller region of the tumor that shows contrast enhancement on T1-weighted contrast-enhanced MR imaging scans. Radiosurgery is certainly not a cure for brain tumors, but it does offer an adjunctive form of treatment that is clinically effective, safe, and cost effective. The simplicity of the treatment, the fact that it interferes very little with normal life activities, and the virtual lack of peri-operative complications make gamma knife radiosurgery attractive to both patients and referring physicians.

**REFERENCES**


Original Article

Could Meningiomas at Certain Locations at the Skull Base have a Higher Incidence of Post-operative Pseudomeningocele and Consequent Communicating Hydrocephalus than Others? (A Retrospective Analysis)

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ABSTRACT

Background: Meningiomas are frequently associated with postoperative pseudomeningoceles. Communicating hydrocephalus is also a frequent complication of skull base meningiomas. Objectives: Our objective is to perform detailed retrospective analysis to determine whether certain locations have a particular predilection to develop a pseudomeningocele and consequent communication hydrocephalus. Patients and Methods: 78 patients were included in the study. A retrospective analysis was performed. The volume of the meningocele was quantified in cubic milliliters to obtain a quantitative variable suitable for statistical inference, correlation and regression. A one way ANOVA test was used for testing of hypothesis using an alpha of 0.01 and a tabulated F value of 3.19. Results: Analyzing the available data revealed a calculated F value of 7.33 and an R² of 0.009 towards tumor location with a tendency towards clinoidal meningiomas. This location showed the highest incidence of pseudomeningoceles and need for shunts. Conclusion: This study was carried on a significant patient cohort and has established a significant difference between meningiomas at various locations and the development of pseudomeningocele and possible consequent communicating hydrocephalus. Meningiomas at the region of the anterior clinoid process have had the highest incidence and the larger number of patients requiring shunts. Meningiomas at the caraniocevical junction came second in place. Other factors that have previously been shown by others to correlate as well as our study include, blood loss and length of the surgical procedure. Key words: pseudomeningocele, communicating hydrocephalus, skull base meningiomas, retrospective analysis.

INTRODUCTION & AIM OF THE WORK

Surgery of skull base meningiomas is the surgery of complications because its outcome not only depends on surgical technique but also on the ability to manage post operative complications frequently associated with such tumors. One of the complications that have been frequently reported but very rarely studied is pseudomeningocele and possible communicating hydrocephalus that may be associated with it. In contrast to spinal pseudomeningocele, cranial pseudomeningocele especially following skull base meningioma surgery has been very rarely studied[6-9]. The available literature lacks comprehensive reports on its incidence, causes, course and best means of its management. The issue of a possible link to certain meningiomas at certain locations has also been rarely studied. Accordingly, the aim of this study is to compare and contrast the mean incidence of pseudomeningocele and possible hydrocephalus developing following surgical resection of skull base meningiomas at various locations in the skull base and possible link to other factors that may have a relationship or a predictive value on the development of pseudomeningoceles and possible association with hydrocephalus following the surgical resection of skull base meningiomas at various locations in the skull base.

MATERIAL & METHODS

This study is a retrospective analysis carried out on 78 patients with skull base meningiomas at various locations operated upon in the period between January 2011 and June 2013 at Kasr El-Aini university hospital and Nasser institute for research and treatment. All patient data were prospectively collected and retrospectively analyzed at the end of the study. Patients were followed up for a period ranging between six months and two years. Patients were randomly collected from various neurosurgeons each with a good workload and more than ten years of experience with various tumors at the skull base. An emphasis was made on data that could have a particular correlation or predictive outcome with
pseudomeningocele development including: Age, gender, clinical presentation, preoperative radiological findings, need for preoperative embolization, operating room time, intraoperative blood loss, use of a graft in reconstruction of the skull base, presence or absence of preoperative hydrocephalus, surgical approach used, presence of a good arachnoid plane for dissection, radicality, clinical outcome, volume of pseudomeningocele, time till its disappearance and the need for shunting.

Patients operated upon for pathologies in the skull base other than meningiomas were excluded from the study. Patients who had residual tumor with a possible obstructive origin for hydrocephalus were also excluded from the study.

Randomization strategy:
Patients were taken at random from operating room records of various neurosurgeons provided the neurosurgeon had a long history of operating at the skull base of more than 10 years and that the patients meet the inclusion criteria described above. Study design was reconstructed so that the statistical analyst was blinded to individual surgeons data.

Statistical methods:
The study was designed as a more than two independent groups observational study. A (p value greater than 0.01) was considered statistically significant. Cases were classified into groups according to tumor location. The study was conducted as a one-way ANOVA after performing a test of homogeneity for groups. Fisher tables were used using 6 as a degree of freedom for the numerator and 71 as degree of freedom for the denominator. At this degree of freedom and an alpha of 0.01 a tabulated value for critical F was used as 3.19. A multilayered bivariate analysis was then done for performing a correlation regression analysis. All statistical analysis was done using an SPSS 21 statistical package (IBM Inc.)

RESULTS
Ages of patients included in the study were between 15 and 62 with a range of 47, a mean of 44.23, and a median of 45.00 and a standard deviation of 8.654 years. The male to female ration was 1:4 with 20% of patients being males and 80% females.

Spheno-orbital meningiomas (en-plaque) were the most frequently encountered tumors in this study representing 30% of cases followed by clinoidal meningiomas representing 20% of cases, cranio-cervical junction meningiomas 18%, olfactory groove meningiomas 12%, tuberculum sella meningiomas 10%, cerebello-pontine angle and petroclival meningiomas and other middle fossa and cavernous sinus meningiomas each representing 5% of cases included in the study.

Proptosis was the most common presenting symptom occurring in 30% of cases followed by a complex of disorders of extra-ocular muscle motility and diminution of vision in 28% of cases and loss of smell with diminution of vision and features of elevated intracranial pressure in 22% of cases, followed by neck pain in 12% of cases and a complex of fifth or seventh cranial nerve palsies or lower cranial nerve paralysis and long tract signs in 8% of cases.

Radiologically only 20% of patients had a hyper intense signal on T2 weighted imaging in white matter on preoperative imaging denoting absence of a good arachnoid plane of dissection, while 80% of patients showed absence of this radiological sign which also correlated well with radicality of resection.

The fronto-temporal epidural approach was the most commonly used approach being used in 70% of cases in this study, this was followed by the trans condylar approach, the bifrontal interhemispheric approach, anterior or combined petrosal approaches or the retro sigmoid approaches representing the remaining 30% of cases. 58% of cases were totally resected while 42% of cases were sub totally resected. 38% of cases had a graft used to close the dura while 68% had no graft used for dural closure.

78% of patients showed improvement after surgery while 18% remained the same while 4% of patients became worse after surgery.

Regarding the volume of pseudomeningocele, which is the main objective of the study. The minimum volume of CSF was 0 ml and the maximum amount was 260 ml with a range of 260 ml a mean of 69.32 ml and a median of 50 ml and a standard deviation of 61.713 ml. Also a box and whisker plot revealed absence of asterix outliers and a histogram with normal curve shown on the histogram revealed a normal distribution of data. The same also applied to the rest of numerical variables included in the study, which included: amount of blood loss during surgery, time of the operative procedure and time needed till cyst disappearance.
Figure (1): A box plot showing absence of outliers for meningocele volume.

Figure (2): A histogram with curve showing a normal distribution and consequent suitability for hypothesis testing.

**One-way analysis of variance ANOVA**

For a testing of hypothesis of $H_0$: that the mean volume of pseudomeningocele and possible communicating hydrocephalus for tumors at various locations at the skull base is equal and an $H_1$: that the mean volume of pseudomeningocele and possible communicating hydrocephalus is not equal Fischer test was used and accordingly at an alpha of 0.01, and degree of freedom for the numerator of 6 and a degree of freedom for the denominator of 71 a critical F value of 3.19 is taken. Calculating the ratio of the mean of squares within groups to mean of squares between groups revealed a calculated F value of 7.334, which rejects $H_0$. According to the set p value this confirms that the mean incidence between groups is not equal. The location with the highest incidence was clinoidal meningiomas followed by craniocervical junction meningiomas. Also the only cases that required shunting were clinoidal meningiomas in 2 cases with an incidence of 2.6%.
Correlation regression analysis

Firstly, a scatter diagram was plotted using the volume of pseudomeningocele as the y axis and using other variables as the x axis repeatedly taking all other variables one at a time. This gave an $R^2$ of 0.009 indicating a significant relationship. Two distinct exponential relations could be drawn. The first was between volume of CSF in pseudomeningocele and tumor location as has been proven by the one-way ANOVA and the second was between the volume of pseudomeningocele and the time taken for disappearance of the pseudomeningocele.

DISCUSSION

Although cranial pseudomeningocele is a complication frequently reported following surgical resection of skull base meningiomas, very few reports have attempted a detailed study of this complication. The available literature is lacking with regards to this issue and only two reports have attempted a detailed study of this issue. The issue of wheather certain locations have a particular predilection for developing pseudomeningocele and possible genesis of communicating hydrocephalus was not studied in details (4-6).

The mean age of our study group is 44.23 years with a 4 to 1 female to male ratio. Meningiomas were divided into 7 groups according to tumor location with Spheno-orbital meningiomas 30%, clinoidal meningiomas 20%, caraniocervical junction meningiomas 10%, olfactory groove meningiomas 18%, tuberculum sella meningiomas 12%, cavernous sinus and other middle fossa meningiomas 5% and cerebello-pontine angle and petroclival meningiomas 5%. This coincides with the incidence reported by others for similar series (7-11).

Measuring the volume of CSF in the pseudomeningocele was done on a postoperative CT scan without contrast. The volume was measured by multiplying length by width and then breadth on CT scan and on follow up. The measurement was expressed in cubic milliliters. Measuring CSF volume as a quantitative variable was devised as a method for plotting a variable that could be quantified in a way that would make it possible to make statistical inference accurate enough and in the mean time allow for a sound testing of hypothesis. Accordingly, the volume ranged from 0 to 260 ml$^3$ with a mean of 69.32 ml$^3$ and a median of 50 ml$^3$. The same technique was previously used for measuring the volume of CSF in spinal pseudomeningoceles.

Using one way ANOVA revealed a calculated F value of 7.33 against a critical tabulated F value of 3.19 and an $R^2$ of 0.009. This reveals a statistically significant difference between the various groups in the genesis of pseudomeningoceles and consequent communicating hydrocephalus. Clinoidal meningiomas were the location with the largest incidence of postoperative pseudomeningoceles and in fact the only two cases in this series that required shunting were patients with clinoidal meningiomas. Sekhar et al have previously reported on communicating hydrocephalus and pseudomeningocele following surgical resection of skull base tumors in general. Burkhardt et al have reported on predictive factors that may be associated with a higher incidence of postoperative communicating hydrocephalus. They have reported a general incidence of communicating hydrocephalus of 8% in skull base meningiomas when compared to meningiomas at other locations. However, in their article they did not make any communication between hydrocephalus and tumor location. They reported that tumors with preoperative embolization, lengthy surgeries and post operative infection to be the most commonly associated with postoperative hydrocephalus (12,13).

Two factors contradict what has been previously reported. Firstly, the presence of statistically significant differences between the incidence of pseudomeningoceles and consequent hydrocephalus for meningiomas at certain locations particularly clinoidal meningiomas. Secondly, is the lower incidence of patients requiring shunting in our series.

The first factor can be explained by the fact that in their article Burkhardt et al. (13) have classified meningiomas according to location into anterior, middle and posterior skull base meningiomas. They have made no reference to subgroups of meningiomas in each of those locations. Accordingly the higher incidence of hydrocephalus with clinoidal meningiomas reported in our series has been diluted by their being mixed with other subgroups in the same entity. The second factor is that in our series we have used the volume of CSF in the pseudomeningocele as a numerical quantitative variable for drawing conclusions. On the other hand, previous articles have used hydrocephalus as a nominal variable which is less reliable for testing of hypothesis and for correlation. The fact that less patients in our series...
required shunting can be explained by the fact that the policy adopted in this series was to apply CSF diversion only in cases where the pseudomeningocele was progressing or showing an impending rupture or if it has ruptured. Cases that had a stationary course or regressive course were left to absorb spontaneously which has been reflected in a lower number of patients requiring CSF diversion.

A number of authors have noted that communicating hydrocephalus cause by skull base meningiomas is a result of the high protein content of CSF and spilling of blood in the subarachnoid space during meningoia dissection\(^{14}\). The higher incidence of hydrocephalus with clinoidal meningiomas can be accounted for by the fact that these tumors are operated through a trans-Sylvian approach mostly and that the extensive arachnoid dissection in such tumors opening a larger number of cisterns and smearing them with blood may be the main factor explaining the higher incidence of pseudomeningoceles and hydrocephalus.

The presence of an exponential relationship between volume of the pseudomeningocele and the time needed till its disappearance is self explained by the fact that larger cysts require a longer time to absorb.

This study has established a statistically significant difference between the mean incidence of pseudomeningocele and consequent communicating hydrocephalus between various meningiomas at various locations in the skull base. The difference is towards clinoidal meningiomas. However, a more detailed analysis regarding which types of clinoidal meningiomas would develop communicating hydrocephalus more than others have not been determined. Also, in the future we do intend to carry out a more detailed correlation to establish a mathematical relation between both variables that would be able to throw more light into possible etiological factors.

**CONCLUSION**

This study was carried on a significant patient cohort and has established a significant difference between meningiomas at various locations and the development of pseudomeningoceles and possible consequent communicating hydrocephalus. Meningiomas at the region of the anterior clinoid process have had the highest incidence and the larger number of patients requiring shunts. Meningiomas at the caraniocervical junction came second in place. Other factors that have previously been shown by others to correlate as well as our study include, blood loss and length of the surgical procedure.

**REFERENCES**


Original Article

Long Term Outcome of Drainage of Midline Deeply Seated Recurrent Brain Cysts by Ommaya Reservoir

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ABSTRACT

Background: Midline deeply seated brain cysts carry great risk during its surgery especially when they are recurrent and extend vertically via the third ventricle to the floor of lateral ventricle. Objectives: To evaluate the effect of Ommaya Reservoir in controlling recurrent cystic midline pathologies and improve their functional outcome. Patients and Methods: This prospective study was conducted on 19 recurrent cases (13 cystic recurrent craniopharyngiomas 68% and 6 cystic recurrent gliomas 32%) had been treated between June 2005 and June 2011 at neurosurgery department of Zagazig University Hospitals – Egypt, by using Ommaya Reservoir and evacuation of the cyst content to decompress the brain. All cysts had cytological examination of their contents to reconfirm the previous pathological diagnosis. Decompression of the brain cysts was carried out by periodic aspiration of the reservoir according to neurological condition of the patient and radiological assessment of the cyst. All cases received optimum dose of radiotherapy according to the pathology and the surrounding structures except 6 kids younger than 3 years who periodically decompressed by Ommaya reservoir till that age when referred to radiotherapy. All cases were followed up to 36 months. Results: The age ranged from 18M to 43 years in craniopharyngioma group with mean age 16 years and from 19 months to 18 years in glioma group with mean age 6 years. All craniopharingioma cysts were considered responding except 2 cases (10.5%) had reasonable residual. 5 cases (26%) showed reduction in initial volume more than 75% and 8 cases (42%) more than 50%. Amount of aspirated fluid ranged from 5 to 15 mls in craniopharyngioma group and from 10 to 20 mls in glioma group. In 7 of 9 cases (78%) with ventricular dilation improved by cyst decompression and the ventricles became normal within 3 months without the need for a shunt. Visual function improved in 6 of 12 patients and remained stable in the rest of the patients at the end of the follow up period. 2 kids with unstable gait improved. 4 lethargic patients improved and became alert. Neither major clinical deterioration nor mortality reported with this conservative technique during follow up period. Conclusion: Because limited surgery for midline deeply seated recurrent brain cyst does not prevent recurrences and radical surgery carries unacceptable morbidity and mortality, postoperative external-beam radiotherapy has been added to limited surgery in an effort to improve local control. Children younger than 3 years may not be candidates for such radiotherapy because they can develop unusually severe long-term adverse effects. In those patients, stereotactic implantation of an intracystic catheter with Ommaya reservoir may be a valuable alternative treatment option. The benefits of this procedure include temporary relief of fluid pressure by serial drainage, may prolong the interval to or obviate the need for radiation. Key words: Ommaya reservoir (OR) – stereotactic-craniopharyngioma (CP) – cystic glioma (CG)

INTRODUCTION

Midline deeply seated brain cysts carry great risk during its surgery especially when they are recurrent and extend vertically via the third ventricle to the floor of lateral ventricle. One of these pathologies is craniopharyngioma that represents 2.5-4% of all intracranial tumors. Although half of these occur in adults, they account for a greater percentage of childhood tumors (5-13%) and are responsible for 54% of sellar region pathology in children. Peaks occurring at ages 5-10 and 55-65 years\(^\text{40}\). Craniopharyngioma was first described by Zenker in 1857. In 1899, Mott and Barrett stated that craniopharyngioma may arise from the hypophyseal-pharyngeal duct or Rathke’s pouch, but may arise by metaplasia of normally developed anterior pituitary cells. New craniopharingiomas represent 0.5–1.0 per million per year. Craniopharyngiomas are difficult to resect and there is usually significant long-term endocrine disturbance due to pituitary involvement; should the hypothalamus be involved, behavioral changes, obesity, learning and memory difficulties may occur\(^\text{3}\).

The effects of the tumor and its surgical treatment can result in a child with defective vision, in addition to an altered personality with behavioral problems; in some cases, life expectancy may be shortened because of vulnerability to a hypothalamic mediated metabolic crisis. Surgical mortality following attempts at radical resection of craniopharyngioma still high, varying in most series from 0 to 15% mainly due to endocrine, ophthalmologic and neuropsychological disturbances\(^\text{48}\). Recurrence of craniopharyngioma occurs in approximately 35% of patients regardless of primary therapy. Repeat attempts at gross total resection are
difficult and long-term disease control is less often achieved\(^{(38)}\).

Due to the morbidity associated with radical surgical removal, more conservative methods of treatment are currently being attempted, including cyst aspiration and radiotherapy. Intracavitary brachytherapy and use of radioisotopes into craniopharyngioma cyst have been documented in the last two decades which introduced by Pollack\(^{(28)}\).

Radiotherapy has been developed by Kramer\(^{(18)}\) and its role has a major controversy in treatment of craniopharyngiomas, despite evidence that radiotherapy alone provide long-term disease control for most patients, there has been much concern about its potential impact on growth, development and on performance\(^{(2)}\). Radiation therapy is often not used or postponed in children younger than 3 years old to avoid damage that might affect brain development\(^{(6)}\).

Tumors of the central nervous system often have associated cystic components. Gross total resection of the tumor and cyst is often enough to prevent recurrence of the cyst\(^{(20)}\). Lesions in the brain stem, however, are often not surgically resectable. Stereotactic aspiration of brain stem cysts may provide temporary improvement in the clinical status of the patient. However, cysts regularly recur and require multiple aspirations. This necessitates frequent operative procedures and compounds the risk of passing the biopsy probe deep into the neuraxis\(^{(11)}\).

Ommaya Reservoir systems have been placed to access fluid cavities within the brain since their original description in 1963\(^{(26)}\). Ratcheson and Ommaya in 1968 reported a series of 60 patients with implantation of Ommaya Reservoirs\(^{(29)}\).

Stereotactic placement of an Ommaya catheter avoids multiple passes through the neuraxis and allows for aspiration of the cyst in an outpatient setting\(^{(41)}\). This procedure may also be helpful in allowing the surgeon to perform a two-staged approach, whereby first the cyst is drained by the implanted catheter to relieve pressure and complicating symptoms, followed by tumor resection\(^{(34)}\).

Stereotactic neurosurgery offers useful minimal-invasive treatment options in the interdisciplinary treatment regime of craniopharyngioma. These options must especially be considered if the solid part of the tumor is small, if there is a hypothalamic involvement, or if the probability for a complete resection is not favorable\(^{(39)}\).

Stereotactic surgery involves accurate localization of intracranial target using a special frame fixed to the patient’s head, a preoperative imaging study and dedicated computer software\(^{(4)}\). Experience has shown that outpatient stereotactic surgery is safe and effective option for selected patients with brain tumors, and that they are more resource friendly than standard approaches. Implementation of outpatient neurosurgery is not only an organizational but a social, political and cultural challenge. The time has come to embrace this new idea\(^{(29)}\).

**Aim of the work:**

To evaluate the functional outcome of midline deeply seated recurrent predominantly cystic lesions continuously decompressed by Ommaya Reservoir.

**PATIENTS & METHODS**

This analytical prospective study was conducted on 19 recurrent cystic brain lesions at neurosurgery department of Zagazig University Hospitals from June 2005 through June 2011 by using Ommaya reservoir and periodical aspiration. The catheter inserted by free hand in 2 cases (10.5%), CT-guided in 2 cases (10.5%) targeting the cyst center, endoscopically-guided in 2 cases (10.5%), manual Stereotactic technique in 5 cases (26%) and computerized stereotactic technique in 8 cases (42%) targeting the most dependent part of the cyst.

We have two groups: **Group A:** 13 (68%) cystic craniopharyngiomas: All the patients were recurrent and received a course of radiotherapy except 4 cases (21%) who referred for Ommaya reservoir implantation till reaching the acceptable age of radiotherapy **Group B:** 6 (32%) recurrent cystic glioma after surgery, 4 (21%) of them had post-operative radiotherapy and 2 (10.5%) not because of the age (under 3 years). All cases had full CT and MRI evaluation to define the exact topography of lesion.

Moreover, craniopharingiomas were classified by size according to the classification of Yasargil et al.\(^{(38)}\) into (small \(<2\) cm), moderate \([2\) to 4 cm], large \([4\) to 6 cm] and giant \([>6\) cm]). The horizontal extension was classified according to Hoffman into sellar, anterior extension (prechaismatic), posterior extension (retrochaismatic) and lateral extension and also grows into various directions (giant)\(^{(14)}\). The vertical extension classified according to Samii into Grade I: Intrasellar tumor, Grade II: Intracisternal tumor with or without intrasellar component, Grade III: Intracisternal tumor extending to the lower half of 3rd ventricle, Grade IV: Intracisternal tumor extending to the upper half of 3rd ventricle and Grade V: Intracisternal tumor extending to septum pellucidum or lateral ventricle\(^{(32)}\). The inclusion criteria were recurrent monocystic craniopharyngioma and glioma (Cystic component >60% of the tumor volume) and the exclusion criteria were multicystic, solid craniopharyngioma or glioma.

**Cyst Volume Calculation:** It was possible to analyze and compare the pre and the post-treatment tumor volume using the modified ellipsoid volume equation: \[ A \times B \times C \times 0.52 \] where A, B and C are the major diameters measured in the 3 special planes and
0.52 is the correction factor because of the elliptical configuration of the cyst(39).

**Stereotactic Application:** 13 planned cases (68%) for stereotactic application were brought to the radiology suite for each procedure under mild intravenous sedation, and the Leksell G stereotactic frame (Elekta Instruments, Stockholm, Sweden) was attached to the patient’s head. High resolution, thin, 1-mm sliced axial contrast imaging. The data were transferred from CT suit to the workstation at the stereotactic unit either by optical disc or recently through direct cable.

**Target Point:** The length of Ommaya catheter was measured to be directed into the cyst center approximately by using the reformatted CT for the first 4 cases (two giant cysts compromising of right frontal lobe by free hand and two by CT guidance). With advent of stereotactic application, we preferred to target the most dependent portion (13 cases). The rest (2 cases with ventriculomegaly) had a catheter during endoscopic application.

5 cases (26%) were done manually by calculating X, Y, Z of the target point (the most dependent part of the cyst) on CT console and our team work fashioned fixed templates (to avoid any personal calculation errors) based on the Cartesian coordinates of the geometric frame center is 100,100,100 and the coordinates of the right, upper, posterior point of the frame is 0, 0, 0 (Figure III). The entry point was chosen by convention (A transfrontal approach with an entry point 2 to 3 cm off midline at the coronal suture).

8 cases (42%) were managed by computerized stereotactic technique. Geometric space registration of both entry and target points by SurgiPlan software that can easily determine entry point by software calculating both ring and arc angels, target point by calculating X, Y, Z and distance between entry and target points, cyst volume (software calculation). Moreover, visual path that passes through the shortest appropriate trajectory to the cyst floor, avoid superficial cortical vessel, deep cerebral veins, avoid ventricles (if possible) and maintain the trajectory within neuraxis on targeting brain stem cyst on reformatted coronal CT or MRI. Virtual path can be tried on the station prior to surgery (SurgiPlan Software – Elekta).

After appropriate planning, the patient was taken to the operating room for the procedure. Under general anesthesia for kids and local anesthesia for adults, a small skin flap and twist-drill hole is performed at entry point which is predetermined by Leksell SurgiPlan workstation or by convention for the manual use (A precoronal burr hole was used for transfrontal approach into the cyst). A barium-impregnated ventricular catheter with an outer diameter of 2.1 mm and the appropriate length predetermined on the software was used to cannulate all cysts. The stylet accompanying the ventricular catheter was used in place of a standard biopsy probe. No modifications were made to the stereotactic system. A standard guide block and tube were used to direct the catheter into its target. The catheter was then inserted directly through the guide tube to the predetermined target distance. Ommaya Reservoir was inserted and connected to the catheter without right-angle connector. The reservoir was then anchored to the edge of the drill hole with a silk tie in the subgaleal space. Perioperative stress prophylaxis with hydrocortisone and optional single-shot antibiotic are applied. Following the procedure (for CP) the liquid balance is documented in order to detect a temporary central diabetes insipidus, which would require Desmopressin substitution.

**Catheter Insertion:** The standard ventricular catheters typically have holes starting 3 mm behind the tip, and continuing as far back as 18 mm from the tip, so that the cyst needs to be at least 2 cm in diameter to allow all the holes to be within the cyst. Therefore, we shifted from targeting the cyst center to the cyst floor to keep the holes contained inside the cyst to keep optimum function of the reservoir especially after cyst collapse.

**Cyst Aspiration:** Careful intraoperative aspiration of the cyst content as well as postoperative CT scans obtained to ensure accurate position of catheter and adequate cyst decompression. The amount of fluid removed based on the symptoms of the patient and the size of the cyst. We stopped the cyst drainage when more than 15 mL was removed or when the patient had headache, thereby avoiding the complete emptying of the cyst and subsequent traction injury to the surrounding eloquent structures. Cytological examination of the cystic fluid to reconfirm the initial diagnosis by presence of cholesterol crystals in the cyst fluid of craniopharingioma group. Periodical aspiration of the cyst content is performed meticulously through the Ommaya reservoir based on clinical and radiological justification (symptomatic chiasmatic compression, intracranial hypertension or third ventricle amputation).

**Postoperative Radiotherapy:** All patients received fractioned radiotherapy, delivered in 25-30 fractions and at a median time period of 40 days after surgery. The median total dose of radiotherapy was 5000 cGy (range 4000-5400 in all patients). It was postponed for 4 craniopharingioma and 2 cystic glioma kids under 3 years old.

**Follow up:** Along 36 months, every patient was followed up at a regular 3-month interval. Assessment included clinical, neurological, fundus examination, endocrine and functional performance in addition to lab investigations for pituitary functions. CT scan and/or MRI to detect any cyst refill.
**Figure I:** Stereotactic application of Leksell G for lady with recurrent craniopharyngioma after surgery and radiotherapy.

**Figure II:** Calculation of X, Y, Z coordinates (the most dependent part of recurrent craniopharyngioma cyst) by CT and Leksell G fiducials (Manual stereotactic application).
RESULTS

19 cases of deeply seated midline recurrent cysts usually unreachable by the conventional surgery. Managed by Ommaya Reservoir and radiotherapy, 13 (68%) of them were craniopharyngiomas and 6 (32%) were cystic gliomas. Clinical and radiological improvement was achieved in 68% of the cases.

Morphological Results (Both Groups): All cysts showed adequate degree of evacuation of their contents with subsequent cyst reduction except 2 (10.5%) cases that had reasonable residual one in each group. The patients were classified according to volume reduction into Group A: Five cases (26%) showed substantial reduction in which size reduction was > 75%. 4 of them within the craniopharingioma group and one case was large thalamic cyst. Group B: Eight cases (42%) showed considerable reduction in which size reduction was 50%-75%. Four cases within the craniopharyngioma and 4 cases within the glioma. Group C: Four cases (21%) showed fair response. All were within the craniopharingioma group in which size reduction was 25%-50%. Group D: Two cases (10.5%) showed poor response (1 in each group) with size reduction <25%. Two cases (10.5%) showed cyst re-expansion after malpositioning of the catheter and subsequent reservoir dysfunction.

7 out of 9 cases (78%) that had ventricular dilation got smaller in the first follow up CT (3-6 months after the procedure) without the need for shunt placement. 6 cases (32%) inserted with Ommaya catheter non-
stereotactically, 4 of them required stereotactic re-insertion.

The Cranipharyngioma Group included 8 (42%) children (up to 16 years), 4 of them (21%) were younger than 3 years, and 5 (26%) adults (more than 16 years). 8 cases (42%) were male and 5 cases (26%) were female. On preoperative MRI study, the majority of the cases (10 cases) were of moderate to large size and 3 cases were giant according to Yazargil et al, classification\(^\text{14}\). According to sami classification\(^\text{18}\): Five cases (26%) at grade V, 5 cases (26%) at grade IV and 3 cases (16%) at grade III. All cases proved as craniopharyngioma after first surgery by two neuropathologist and reconfirmed on recurrence. All cases had postoperative radiotherapy except those who were younger than 3 years (4 cases). Amount of aspirated fluid ranged from 5 to 15 mls per session for 2-4 times per year.

The Non-craniopharyngioma Group: Six cases (32%) include 4 cases were males and 2 cases were females. Two cases were under 3 years. Regarding the location, 3 cysts were brain stem (pontine, pontomедullary and pontomesencephalic), 2 cysts were purely thalamic and one large cyst was mesodiencephalic. Regarding the histopathology, 3 cysts were astrocytoma grade II, 2 cysts were Juvenile Pilocytic Astrocytoma (JPA) and one post-irradiation pontine cyst. The range of maximum diameter was 20-45 mm (Table III). Amount of aspirated fluid ranged from 10 to 20 mls per session for 3-5 per year.

The Overall Functional Results (Neurological, visual and endocrine function): At admission, 8 of 19 patients experienced deficiencies of visual function. In 11 of 19 patients, impairment of endocrine function was diagnosed. Four of the latter patients had additional visual deficits. Other tumor-related symptoms were cognitive disturbances (3 patients) and hemiparesis (3 patients). Visual function improved in 6 of 12 patients and remained stable in the rest of the patient at the end of the follow up period. The preoperative status did not change in 6 patients with endocrine dysfunction. In 2 of 3 cases had cognitive disturbances, showed improvement after 2 years. Hemiparesis improved significantly in 2 of 3 patients with physiotherapy. 2 kids (10.5%) with unstable gait improved within 9 months. 4 lethargic patients (21%) improved and became alert.

Catheter Related Complications: In one patient who had catheter infection, the catheter was removed and re-inserted after 4 weeks. Another patient had asymptomatic intracystic silent hemorrhage that washed through Ommaya Reservoir by regular saline. One case operated by manual stereotactic technique with small cortical hemorrhage presented with seizure because of the injury of one of the cortical vessel and the patient controlled conservatively and discharged in health. Rapid collapse of 2 large cysts (one in each group) required catheter repositioning after the cyst refill.

Figure IV: A 35-year-old female with recurrent cystic craniopharyngioma managed by Ommaya reservoir insertion and radiotherapy (follow up period 35 months).
Table I: Patient characteristics among craniopharyngioma group (13 cases):

<table>
<thead>
<tr>
<th>Total No. of Patients</th>
<th>13</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>8</td>
<td>61.5%</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>38.5%</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Range (Age)</td>
<td>18m-43y</td>
<td></td>
</tr>
<tr>
<td>Adults (&gt;16 years)</td>
<td>5</td>
<td>38.5%</td>
</tr>
<tr>
<td>Children (&lt;16 years)</td>
<td>8</td>
<td>61.5%</td>
</tr>
</tbody>
</table>

Initial Symptoms

<table>
<thead>
<tr>
<th>symptom</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>12 (92%)</td>
</tr>
<tr>
<td>Nausea-Vomiting</td>
<td>8 (61.5%)</td>
</tr>
<tr>
<td>Seizures</td>
<td>6 (46%)</td>
</tr>
<tr>
<td>Unsteadiness</td>
<td>2 (15%)</td>
</tr>
<tr>
<td>Hemiparesis</td>
<td>3 (23%)</td>
</tr>
<tr>
<td>Visual Symptoms</td>
<td>12 (92%)</td>
</tr>
<tr>
<td>Impaired Consciousness</td>
<td>4 (30%)</td>
</tr>
<tr>
<td>Cognitive Disturbance</td>
<td>3 (23%)</td>
</tr>
<tr>
<td>Amenorrhea</td>
<td>2 (15%)</td>
</tr>
<tr>
<td>Obesity</td>
<td>4 (30%)</td>
</tr>
<tr>
<td>Growth Retardation</td>
<td>2 (15%)</td>
</tr>
</tbody>
</table>

Table II: Response of recurrent craniopharyngioma cyst to Ommaya reservoir and subsequent radiotherapy (13 cases):

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Previous Surgery (S)</th>
<th>RTX</th>
<th>(Maximum Size)</th>
<th>Initial Size</th>
<th>Minimum Size</th>
<th>% Volume Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35 y</td>
<td>F</td>
<td>Combined</td>
<td>RTX</td>
<td>44.22 cm³</td>
<td>3.68 cm³</td>
<td>91.7%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.5 y</td>
<td>M</td>
<td>Bi-frontal</td>
<td>OR</td>
<td>36.14</td>
<td>9.81</td>
<td>73%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6 y</td>
<td>F</td>
<td>RT. FT</td>
<td>RTX</td>
<td>94.56</td>
<td>8.22</td>
<td>91.3%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3.5 y</td>
<td>F</td>
<td>Bi-frontal</td>
<td>RTX</td>
<td>12.88</td>
<td>2.88</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>18 y</td>
<td>M</td>
<td>TS</td>
<td>RTX</td>
<td>25.82</td>
<td>4.8</td>
<td>81.4%</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.5 y</td>
<td>M</td>
<td>Endoscopy</td>
<td>OR</td>
<td>22.62</td>
<td>8.6</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>43 y</td>
<td>M</td>
<td>TS</td>
<td>RTX</td>
<td>12.82</td>
<td>4.72</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3 y</td>
<td>M</td>
<td>Lt. FT</td>
<td>OR</td>
<td>34.44</td>
<td>27.55</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>40 y</td>
<td>F</td>
<td>Bi-frontal</td>
<td>RTX</td>
<td>26.42</td>
<td>11.89</td>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>14 y</td>
<td>M</td>
<td>Rt. FT</td>
<td>RTX</td>
<td>18.46</td>
<td>11</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>33 y</td>
<td>M</td>
<td>TS</td>
<td>RTX</td>
<td>38</td>
<td>26.6</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2 y</td>
<td>F</td>
<td>Bi-frontal</td>
<td>OR</td>
<td>18.22</td>
<td>9.5</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>8 y</td>
<td>M</td>
<td>Rt. FT</td>
<td>RTX</td>
<td>16.8</td>
<td>9.24</td>
<td>45%</td>
<td></td>
</tr>
</tbody>
</table>

Rt. (Right), Lt. (Left), FT.(Frontotemporal), TS.(Trans-sphenoidal),OR (Ommaya Reservoir), RTX (Radiotherapy)
Table III: Glioma Group (6 Cases):

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Location</th>
<th>Surgery (S)</th>
<th>Histopathology</th>
<th>Recurrence Duration</th>
<th>OR±RTX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19M – F</td>
<td>Ponto-medullary junction (20 mm)</td>
<td>Biopsy</td>
<td>Astrocytoma II</td>
<td>4M</td>
<td>OR inserted and periodic decompression until age 3y when radiotherapy launched</td>
</tr>
<tr>
<td>2</td>
<td>6Y- Male</td>
<td>Right thalamic cystic mass filling lateral ventricle (45 mm)</td>
<td>Biopsy of the enhanced fleshy portion</td>
<td>Astrocytoma II</td>
<td>13M</td>
<td>OR with immediate RTX</td>
</tr>
<tr>
<td>3</td>
<td>20M- Male</td>
<td>Large right mesodiencephalic cyst (25 mm)</td>
<td>Biopsy + Cyst aspiration</td>
<td>JPA</td>
<td>6M</td>
<td>OR inserted and periodic decompression until age 3y when radiotherapy launched</td>
</tr>
<tr>
<td>4</td>
<td>5Y- Male</td>
<td>Large cyst with small nodular mass spanning dorsal part of the midbrain and pons (30 mm)</td>
<td>Biopsy of the enhancing nodule with cyst aspiration</td>
<td>Astrocytoma II</td>
<td>3M</td>
<td>OR with immediate RTX</td>
</tr>
<tr>
<td>5</td>
<td>4Y- Male</td>
<td>Large left thalamic cystic mass (40 mm)</td>
<td>Stereotactic biopsy and cyst aspiration</td>
<td>JPA</td>
<td>4M</td>
<td>OR with immediate RTX</td>
</tr>
<tr>
<td>6</td>
<td>18Y-F</td>
<td>Posterior fossa ependymoma</td>
<td>Complete excision + RTX</td>
<td>Ependymoma</td>
<td>2Y – Post RTX- Pontine cyst (20 mm)</td>
<td>OR</td>
</tr>
</tbody>
</table>

DISCUSSION

Microsurgery remains the technique of choice for the treatment of solid tumors, particularly when they are large. Long-term results after multi-modality treatment are not inferior to long-term results obtained by microsurgery. However, when hospital costs are considered, the difference between stereotactic and microsurgical approaches is considerable. Lastly, if we consider morbidity with respect to the treatment of giant cysts, the multi-modal approach should be preferred rather than the microsurgical approach alone(24).

Many procedures have been used in the treatment of intracranial cystic lesions, mainly percutaneous cyst aspiration, marsupialization, percutaneous ventricle cystostomy with or without plasty, and cyst drainage. In some patients, the procedures were unsuccessful and the cyst increased in size, causing neurological disturbances. Therefore, repeated evacuations that include the use of different methods are necessary(7).

Craniohypophyseal cystoma is the most frequent midline intracranial cystic neoplasm of nonglial origin, representing 9% of pediatric brain tumors. In larger series, 54.0 to 94.4% of the evaluated patients had tumors with significant cystic parts. It is important to keep in mind that 90% of pediatric craniopharyngiomas have these characteristics whereas only 10% of craniopharyngiomas are purely solid(22).

Craniopharyngiomas are benign tumors for which the best therapeutic option should be complete resection. However, because of the tumor location, the management of this tumor must be considered differently. In fact, the morbidity associated with radical operation remains high, notably because of adherences to critical surrounding structures such as vascular structures, optic pathways, the pituitary stalk, and hypothalamus. In addition despite radical surgery, recurrences are not rare(9).

Zuccaro demonstrated a 77% rate of total resection with 87% of 153 patients having a hormone deficit(42). According to the literature, the condition in the vast majority of patients will progress to visual and endocrine dysfunction, hypothalamic dysfunction, disorders of hunger, psychiatric disorders, and a poor quality of life(12).

In the series of Yasargil et al.(39), the overall mortality rate was 17% and the recurrence rate was 7% even after aggressive radical excision of the tumors. In addition, marked differences in the rates of good outcomes (range, 52%-87%), according to the
experience of the surgeons, were reported for the radical surgery-treated groups(32).

Over the last 40 years there exists an open-ended controversy concerning the best treatment for craniopharyngioma. One group favors open surgery which is in many cases associated with increased morbidity. The other group proposes minimal-invasive procedures combined with subsequent radiotherapy to minimize risk and morbidity(22).

Due to the high variability in the appearance of these tumors the treatment strategy must be individually tailored to the patient(22).

In the past decade, the goal of treatment of craniopharyngioma has been not only to obtain long-term tumor control but also to preserve the patient’s quality of life(8).

Preserving the patient’s quality of life and being the great majority of craniopharyngiomas having significant cystic component have pushed many neurosurgeons to look for more long term conservative technique based on Craniopharingioma is a benign chronic disease.

An insertion of a catheter into a cystic craniopharyngioma may prevail over the transient success of a cyst fenestration by allowing repetitive drainage of the tumor cyst and the opportunity of instillation of intracystic substances. Different neurological techniques are employed for the placement of catheters(30).

We included in this series the difficult recurrent complicated monocystic craniopharyngioma and glioma that their cystic component more than 60% and this agrees with the definition of cystic craniopharyngioma in the literature that considers a cystic craniopharyngioma to be one in which greater than 60% of the tumor volume is cystic(33).

In our series, we have had overall successful rate of 68% (>50% reduction of the initial cyst volume) over 36 months of follow up. Thirteen cases (9 cases of craniopharyngioma and 4 cases of glioma) 68% passed 50% cyst volume reduction including 2 cases of radiotherapy received craniopharingioma completely disappeared at the end of the follow-up period. Cavalleiro et al, considered cystic craniopharyngioma to be controlled when a tumor decreased more than 50%(8). However, the comparison between studies in terms of cystic craniopharyngioma is very difficult because, whereas some authors considered cyst volume stability a good morphological result. Other authors considered that cyst reduction should reach 50% of the initial volume 7 of 9 cases (78%) that had ventriculomegaly improved by cyst decompression without the need of a shunt. However, one patient developed secondary hydrocephalus and was finally shunted. Lena et al, reported 7 children were shunted before surgery and only 3 had permanent shunt(19).

That means 4 out of her 7 cases were not shunt dependent and may improve by simple cyst decompression. In Cavalleiro series, 6 out of 19 cases with hydrocephalus did not need a shunt(8).

We found our results in this selected group of recurrent midline cysts were comparable to other modalities. Over 36 months of follow up, vision improved in 6 of 12 cases (50%) and remained stable in the rest. the visual field deteriorated in 3 cases (25%) and remained stationary in the rest of the cases. No improvement in endocrine function in 6 of 11 cases (54.5%) who kept on hormonal support. However, In the group of children, following stereotactic treatment by Michael and Guido, the patients’ vision improved in 61%, remained unchanged in 39%, and the visual field ameliorated in 75% or remained stationary (25%). While 6% experienced temporary minor visual degradation, which recovered within days, there was no permanent visual deficit due to stereotactic surgery. Following cyst drainage the endocrinological state remained unchanged in 93%(26). Cognitive function and hemiparesis showed improvement in 2 of 3 patients supported with psychotherapy and physiotherapy. Gait improved in two kids.

Neither major clinical deterioration nor mortality reported with this conservative technique during follow up period (36 months). This agrees with large recent series of Michael and Guido who stated that no procedure related lethality or permanent morbidity was observed with 208 patients with craniopharyngioma were performed in the Department of Stereotactic Neurosurgery in Freiburg, Germany From 1990 to 2010(23).

Rapid decompression of two large nontestereotactically inserted cysts (one in each group) might push the catheter into the subarachnoid space with subsequent malfunction and required repositioning after the cyst refill. We shift from targeting cyst center to the cyst floor that ensured catheter accommodation by cyst and minimized the malpositioning. In our study, 4 out of 6 patients who had surgical implantation had undergone new implantation stereotactically.

The standard ventricular catheters typically have holes starting 3 mm behind the tip and continuing as far back as 18 mm from the tip, so that the cyst needs to be at least 2 cm in diameter to allow all the holes to be within the cyst. Steinbok and Hukin have used a modified catheter containing holes that go back only 8 mm from the tip to make the margin of greater safety(35). Furthermore to minimize leakage of cyst content into subarachnoid space, they tried to insert the catheter using a push technique with a stylet in place or a minimal incision, if one is using an open approach to visualize the cyst directly(16).
Stereotactic methodology especially when supported with the software, obviously reduced the catheter malposition and reservoir dysfunction for many reasons: 1) Reduced the incidence of catheter malpositioning; 2) The stereotactic created cyst wall hole is too small to leak; 3) Ideal placement of the tip of the catheter into the most dependent point inside the cyst with respect to its elliptical contour is ensured; 4) Surgical insertion of catheter is not a good idea as surgical disturbance of the peri-cystic adhesions and cisterns. Moreover, normal brain tissue retraction through the surgical corridor predispose to generous cyst wall gapping; 5) it is preferable to use the visual path in penetrating the cyst wall through the most accessible thick part of the cyst wall.

In report of the Canadian experience, Hukin et al, stated that the complications of the non-stereotactic catheter insertion occurred in 7 of 19 patients (37%) and included the acute epidural and intraventricular hemorrhage in a patient with a previously undiagnosed coagulation defect, intracisternal blood (2 patients), fluid collection outside the cyst (1 patient), and contrast leakage on postoperative CT scan after instillation of contrast into the cyst (3 patients)\(^{(16)}\). However, Pettorini et al, advocated that neuro-endoscopic positioning of the catheter is a safer option rather than open or stereotactic approaches\(^{(27)}\). Bartels et al, did not find a difference in complications between the different surgical methods (free hand, operative, endoscopic and stereotactic)\(^{(6)}\).

There are anatomic constraints that may limit the stereotactic accessibility of a craniopharyngioma cyst which is related to the infra- or suprasellar location and the vulnerability of the adjacent critical structures such as optic apparatus, pituitary gland, and hypothalamus\(^{(16)}\). However by using the SurgiPlan station and its visual path, we secured these critical structures. Stereotactic neurosurgery provides save, minimal invasive and cost-efficient options in the treatment of childhood craniopharyngioma\(^{(23)}\).

Chronic progressive shrinkage of the cyst might have caused the movement of one or more holes of the ventricular catheter into the subarachnoid space. Therefore, we were intended to push the catheter deep inside the cyst. Steinbok and Hukin used a modified ventricular catheter with holes over 5 mm instead of the regular one over 15 mm to get optimum function of the reservoir.

Perhaps the craniopharingiomas are not tumors themselves but embryonic immune defects. Indeed, few genetic changes are found in craniopharingiomas. The balance between the aggressiveness of the tumor and the patient’s immune response will determine the winner of this battle\(^{(37)}\). This idea pushed some surgeon to try Interferon \(\alpha\) as new modality for intracisternal injection.

The mechanism of action of Interferon \(\alpha\) in tumor control is not definitively known but preliminary studies have suggested that it may be tumoricidal by activating apoptosis with the simultaneous modulation in patient immune response\(^{(17)}\).

In a retrospective study of Schubert and his colleagues compared three groups of 32 children (<18 years of age) with craniopharyngioma. The first group included patients treated with microsurgical resection. The second group underwent stereotactic cyst drainage, implantation of a Rickham catheter, and fractionated three-dimensional conformal multi-field radiotherapy with 54 Gy volume dose. The third group received various combined approaches. In this study, the 8.5-years of freedom from tumor recurrence was 24% in the resection group as compared to 71% for children with combined stereotactic and radiotherapeutic treatment \((p = 0.05)\). The target volume can be significantly reduced by the evacuation and drainage of large cysts preceding fractionated external radiation therapy. There was no permanent postoperative morbidity related to stereotactic cyst puncture and drainage\(^{(34)}\).

Because limited surgery does not prevent recurrences and radical surgery carries unacceptable morbidity and mortality, postoperative external-beam radiotherapy has been added to limited surgery in an effort to improve local control. The literature seems to support this approach, with a reported long-term control of approximately 80-95% at 5-20 years and a low risk of long-term morbidity\(^{(36)}\). Nowadays, craniopharyngioma must be considered a complex molecular disease, and a detailed explanation of the mechanisms underlying its aggressive biological and clinical behavior, despite some benign pathological features, would be the first step toward defining the best management of craniopharyngioma. Indeed, advances in the knowledge of the molecular mechanisms at the base of craniopharyngioma oncogenesis will lead to comprehension of the critical checkpoints involved in neoplastic transformation. The final research target will be the definition of new biological agents able to reverse the neoplastic process by acting on these critical checkpoints\(^{(46)}\).

Cystic lesions of the brain stem often have substantial mass effect and may be responsible for neurological deterioration in patient. Drainage of the cystic lesion often leads to neurological improvement\(^{(1)}\).

Surgical resection of cystic lesions of the brain stem carries substantial risks; often gross total resection is not possible and may lead to recurrence. Even with the gross total resection, cysts may recur\(^{(39)}\).

Stereotactic aspiration of cystic lesions of the brain stem is an accurate and safe method that carries low surgical risks\(^{(41)}\).
Cyst recurrence after stereotactic aspiration is common and often requires multiple procedures to control cyst growth. Brain stem cystic regression is a gradual process and can take from 3 to 12 months\(^{(31)}\).

In report of Rogers and Barnett, who presented 21 deeply seated brain cysts including 2 cases of craniopharingioma and one case of brain stem cystic glioma, they stated that stereotactic insertion of Ommaya Reservoir system did achieve cyst control at follow up period of 4 to 114 weeks\(^{(30)}\).

In our series, we did achieve cyst control at relatively long follow up period (36 months). Moreover, in 2 cases under 3 years, we carried out periodical aspiration through Ommaya Reservoir till the appropriate age for of radiotherapy without neurological deterioration.

The hyperfractionated radiotherapy be used to reduce the possibility of radiation injury to normal surrounding brain in the treatment of pediatric brain stem glioma. However, a possibility remains that, even with this, intratumoral radiation injury can occur and cause clinical deterioration\(^{(13)}\).

We believe that Periodical decompression of brain stem and diencephalic cysts and their low grade histopathological features without malignant transformation together with appropriate radiotherapy helped make our patients stable over relatively long follow up period.

**CONCLUSION**

Because limited surgery for midline deeply seated recurrent brain cyst does not prevent recurrences and radical surgery carries unacceptable morbidity and mortality, postoperative external-beam radiotherapy has been added to limited surgery in an effort to improve local control. Children younger than 3 years may not be candidates for such radiotherapy because they can develop unusually severe long-term adverse effects. In those patients, stereotactic implantation of an intracystic catheter with Ommaya reservoir may be a valuable alternative treatment option. The benefits of this procedure include temporary relief of fluid pressure by serial drainage, may prolong the interval to or obviate the need for radiation.

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Effects of Suboccipital Craniectomy with and without Duraplasty on Chiari Type-one Malformation

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Department of Neurosurgery*; Radio diagnosis ** Faculty of Medicine, Zagazig University, Egypt

ABSTRACT

Background: Chiari Malformation type 1 (CM-I) is a congenital disease characterized by downward decent of the cerebellar tonsil and crowding in the craniocervical junction area. There are still obvious controversies for the optimum surgical strategy for Chiari malformation type 1 especially if associated with syringomyelia. Objectives: to determine the results of bony decompression with and without duraplasty on treatment of Chiari type 1 malformation patients. Patients and Methods: a retrospective study was undertaken on the medical records and magnetic resonance imaging (MRI) scans of 20 surgical corrections of Chiari malformation type I performed at our institution from 2007 to 2011. The age and sex of the patient, the presence of syringomyelia, the type of surgery (duraplasty or non duraplasty), and the clinical outcome were determined. Results: Of the eight patients who did not undergo duraplasty, four patients without syringomyelia showed improvement postoperatively; of the four patients with syringomyelia, three showed improvement, including two with a decrease in the cavity size. One patient showed improvement in symptoms but the syringomyelia was unchanged. The cavity size increased in the one patient who did not show improvement. Among the 12 patients who underwent duraplasty, improvements were noted in four of the five patients without syringomyelia and in all of the seven with syringomyelia. Conclusion: Suboccipital craniectomy, C1 laminectomy, and duraplasty for the treatment of Chiari I malformation may lead to a more reliable reduction in the volume of concomitant syringomyelia, compared with Suboccipital craniectomy and C1 laminectomy alone. However, there seems to be a subset of patients whose symptoms will resolve and whose syringomyelic cavity will decrease with the removal of bone only. Further studies are needed to better characterize these patients, to determine which patients with Chiari I malformation are better served with bony decompression only, and which will require duraplasty to resolve their syringomyelia. Key words: Chiari type I, syringomyelia, suboccipital craniectomy, duraplasty

INTRODUCTION

Chiari malformation type I (CM-I). is a congenital disease characterized by downward decent of the cerebellar tonsil and crowding in the craniocervical junction area, which was first described by Hans Chiari over one century ago[8].

Generally, about 50~70% CM- I cases are associated with syringomyelia (SM), which will slowly lead to chronic and sometimes irreversible myelopathy[3,15,16,33]. Although many individuals with CM-I are asymptomatic, the malformation can cause headaches, ocular disturbances, cerebellar ataxia, lower cranial nerve signs, or spasticity[3]. The onset of symptoms is usually in the third decade of life. Since many cases of CM-I are asymptomatic, prevalence may not be accurate. However, a retrospective investigation of brain magnetic resonance images (MRIs) reported that the prevalence of CM-I was one case in 1,280 individuals[31].

Surgery is the only way to cure this disease. There are still obvious controversies in current surgical strategies although much operative progress has been made in the last few decades and the expansion of posterior fossa volume has been widely accepted as the surgical goal[12,15,16,18,24].

The various surgical approaches attempted have included suboccipital craniectomy, syringostomy, obex plugging, syringosubarachnoid shunting, ventriculoperitoneal shunting and fourth ventriculosubarachnoid shunting[3,7,9,11,13]. Posterior craniocervical decompression is the procedure currently most used for treating CM1 (alone or in association with syringomyelia, in the absence of hydrocephalus).

Patients with syringomyelia have a poorer outcome with surgery, compared with those without syringomyelia[6,21]. Cranioventricular junction decompression in hindbrain-related syringomyelia achieves an improvement in symptoms in approximately two-thirds of patients[21]. In a review of patients who underwent Chiari decompression with or without duraplasty, Matsumoto and Symon[21] noted no difference in the reduction of syringomyelia and Munshi et al. [25] showed that regarding the improvement in symptoms, patients doing bony decompression without duraplasty had a significantly bad outcome, compared with those who underwent duraplasty.

In the present report, we review our experience with the treatment of CM-I in patients who underwent decompression with or without duraplasty.
PATIENTS & METHODS

A total of 20 symptomatic patients with CM-I (8 men and 12 women; age range, 23-62 years; median age at surgery was 40.5 years were treated by surgery at the Department of Neurosurgery of our hospital between 2007 and 2011. Preoperative MRI scan revealed that 11 cases were associated with SM. We retrospectively analyzed the surgical results with a minimum of 1 year of postoperative follow-up (mean 36 months). All included patients have received at least 1 preoperative and 1 postoperative MRI scan in this study.

Preoperative Clinical Symptoms

Preoperative neurological examinations were routinely performed. Sensory disturbance (36.4%), pain (27.3%) and motor weakness and muscular atrophy (27.3%) were the three main symptoms in CM-I patients with SM. Pain (44.5%), cerebellar dysfunctions (33.3%) and cranial nerve dysfunctions (22.2%) were the three main symptoms in patients without SM. Further details are presented in Table 3.

Preoperative Imaging

Patients generally underwent magnetic resonance imaging (MRI) preoperatively and the diagnosis of CM-I was defined as tonsillar herniation extending at least 5mm below the foramen magnum without meningocele and a descent of the cerebellum and the fourth ventricle (14). SM was found by preoperative MRI in 11 patients. MR imaging was performed with a 1.5-T Philips Achieva system by using a head coil with the patient in supine position. MR imaging was done in axial, and sagittal scans with the following parameters: T1WI (TR148-97/TE2-15), T2WI (TR4400-4800/TE110) and FLAIR (TR6000/TE120-TI2000). Section thickness was 5 mm with a gap of 1 mm. All MRI examinations were performed at the initial and follow up examinations.

Surgical technique:

The specific surgical procedure, i.e. non-duraplasty (without durotomy) or duraplasty was chosen by each surgeon on the basis of personal preference and training. All patients underwent decompressive sub occipital craniectomy extending at least 2 cm above the foramen magnum, with bilateral removal of the atlas laminae. Eight of the patients then underwent removal of all dural scarring or bands on the outside of the dura, twelve patients underwent bone removal and dural grafting using the fascia lata.

Clinical and radiological Follow-up was performed postoperatively at one, three, six months and one year. For patients with postoperative MRI scans, the change in the size of the syringomyelia cavity was classified as improved (decreased maximum diameter), unchanged or increased. This study was approved by the local ethics committee.

RESULTS

Of the eight patients who did not undergo duraplasty, four patients without syringomyelia showed improvement postoperatively.

Of the four patients with syringomyelia, three showed improvement, including two with a decrease in the cavity size. One patient showed improvement in symptoms but the syringomyelia was unchanged. The cavity size increased in the one patient who did not show improvement (Table 2).

Among the 12 patients who underwent duraplasty, improvement was noted in four of the five patients without syringomyelia and in all of the seven with syringomyelia. All of the patients with syringomyelia underwent postoperative MRI; all showed a decrease in the volume of their syringomyelia and clinical improvement (Table 3).

When the dura was opened, the surgical complications included two cases of cerebrospinal fluid (CSF) leaks associated with aseptic meningitis in one patient; one case of subgaleal CSF or seroma collection that subsequently resolved with conservative treatment only; one case of superficial wound infections; and postoperative occipital nerve pain in one patient. When the dura was not opened, the only complication was a superficial wound infection that resolved.

Table 1: Clinical and surgical groups of the patients. CM: chiari malformation, SM: syringomyelia. PFD: posterior fossa decompression.

<table>
<thead>
<tr>
<th>Patient group</th>
<th>PFD only</th>
<th>PFD+duraplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiari malformation (CM) 9</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>CM+SM 11</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>
Table 2: Clinical and radiological summary of the patients.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Syringomyelia</th>
<th>Duraplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>F</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td>M</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>F</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>M</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>5</td>
<td>39</td>
<td>F</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>F</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>F</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>8</td>
<td>55</td>
<td>M</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>9</td>
<td>27</td>
<td>F</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>10</td>
<td>29</td>
<td>F</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>11</td>
<td>53</td>
<td>F</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>12</td>
<td>42</td>
<td>M</td>
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<td>NO</td>
</tr>
<tr>
<td>13</td>
<td>62</td>
<td>F</td>
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</tr>
<tr>
<td>14</td>
<td>23</td>
<td>F</td>
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<td>YES</td>
</tr>
<tr>
<td>15</td>
<td>28</td>
<td>F</td>
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<td>YES</td>
</tr>
<tr>
<td>16</td>
<td>34</td>
<td>M</td>
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<td>YES</td>
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<td>29</td>
<td>F</td>
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<td>18</td>
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<td>M</td>
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<td>YES</td>
</tr>
<tr>
<td>19</td>
<td>52</td>
<td>F</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>20</td>
<td>55</td>
<td>M</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

Table 3: Preoperative symptoms/signs of patients. CM: chiari malformation, SM: syringomyelia.

<table>
<thead>
<tr>
<th>Symptom/sign</th>
<th>CM</th>
<th>CM+SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sensory disturbance</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Weakness &amp; muscular atrophy</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Gait problems or ataxia</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Cranial nerve dysfunction</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4: Clinical summary of patients who did posterior fossa decompression only.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Syringomyelia</th>
<th>Syringomyelia decrease</th>
<th>Symptom improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>12</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>13</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>19</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>20</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 5: Clinical summary of patients who underwent posterior fossa decompression and duraplasty.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Syringomyelia</th>
<th>Syringomyelia decrease</th>
<th>Symptom improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>no</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>no</td>
<td>-</td>
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</tr>
<tr>
<td>14</td>
<td>yes</td>
<td>yes</td>
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</tr>
<tr>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>16</td>
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<td>-</td>
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DISCUSSION

A popular hypothesis concerning the pathogenesis of CM-I is that the hindbrain tissues are dislocated into the spinal canal after birth due to an overcrowded posterior cranial fossa which is caused by the retarded development of the occipital bone during the embryonic period. However, the pathogenesis of SM remains controversial. The 3 main theories which attempt to explain the formation of SM are Gardner's hydrokinetics, Williams' intracranial and intraspinal pressure dissociation and Oldfield's CSF and spinal substance penetration, none of which is superior to any other. Partial obstruction in the foramen magnum area blocks the normal circulation of CSF which is a major factor in the development and progression of SM. Morphological changes in the subarachnoid space are important in the development and progression of SM in that CM-I patients usually have increased atlanto-occipital fascia thickness and narrowed or even obstructed cisterna magna, in addition to structural abnormalities. The longer the duration of CM-I and the more severe the condition, the narrower the subarachnoid space. The false membrane at the orifice of the spinal canal is one of the causes of intraspinal canal fluid accumulation and the formation of a syrinx. Reduced posterior fossa capacity and narrowed occipitocervical subarachnoid spaces are key factors in the development of CM-I complicated with SM. CM-I is congenital, whereas SM is acquired. When the obstruction of the subarachnoid space reaches a certain extent, SM may occur. At present, the main treatment of CM-I complicated with SM is surgery. However, surgical treatment retards the disease's progression rather than curing the damage caused to the spinal cord.

Although the exact mechanism for the formation of the syringomyelia in Chiari malformation is still controversial, there is general agreement on the importance of decompressing the craniovertebral junction in treatments for Chiari malformation and syringomyelia. Suboccipital decompression, with or without duraplasty, serves to relieve the bony compression at the craniovertebral junction. However, most authors differ on the usefulness and safety of additional procedures, such as duraplasty, syringosubarachnoid shunting or obex plugging. There is no direct neurological deficit that has been demonstrated as a result of tonsillar resection. However, the surgical effect of cerebellar tonsillectomy is questioned as tonsillar manipulation may lead to further arachnoidal adhesions later on at the foramen magnum with aggravation of syringomyelia and symptoms.

If the purpose of surgery for CM-I is enlargement of the cisterna magna, thereby allowing improved CSF flow, adequate bone removal must be obtained in all patients.

Three of our four patients with syringomyelia showed improvement with bone removal only, and two (50%) of the four showed a decrease in the size of the syringomyelia. The two patients with a decrease in cavity size showed an increase in CSF space behind the cerebellum. The patient with no change in the cavity size showed no change in the CSF space behind the cerebellum. It is also possible that this patient harbored or developed arachnoid scarring or subarachnoid adhesions.

All of the seven patients with syringomyelia who underwent duraplasty showed improvement and all seven (100%) showed a decrease in the size of the cavity. Four of the five patients without syringomyelia who underwent duraplasty showed clinical improvement.

It therefore seems that duraplasty provides a better chance of enlarging the size of the cisterna magna, this agree with results of Munshi et al; 2000 whom reviewed the medical records and magnetic resonance imaging (MRI) scans of 34 surgical corrections' of Chiari malformation performed from 1988 to 1998. The presence of syringomyelia, the type of surgery (duraplasty or non duraplasty), and the clinical outcome were determined.

Munshi et al; 2000 reviewed Eleven patients whom underwent posterior fossa decompression (PFD) and C1 laminectomy without duraplasty. Eight (73%) of these patients had an improvement in symptoms. Seven of the 11 patients had syringomyelia. Of the six patients who underwent follow-up MRI, three (50%) had a decrease in the size of the syringomyelia, and all three
had clinical improvement. Munshi et al; 2000 also noted a morphometric increase in posterior fossa volume on postoperative MRI scans in these three patients, which was not observed in those without improvement. Two of the three patients whose syringomyelia did not decrease on follow-up MRI scans worsened clinically, and one underwent a reoperation with duraplasty. Twenty-three patients underwent combined PFD, C1 laminectomy, and duraplasty. Twenty (87%) of these patients had improvement. Twelve of the patients who underwent duraplasty had syringomyelia; nine underwent follow-up MRI. All nine of these patients (100%) had a decrease in the cavity size, including eight with clinical improvement, these results agree with our results as in the post fossa decompression alone group out of eight patients only one patient (12.5%) did not show clinical improvement and seven patients (87.5%) show symptom improvement, while in the duraplasty group out of the twelve patients only one patient (8.3%) did not show clinical improvement and eleven patients (91.7%) show symptoms improvement.

Complications such as transient postoperative swallowing problems, electrolyte imbalances and cerebellar infarctions have been reported after Chiari decompression [12,28]. CSF leaks occurred in two of our patients. The wounds were resutured, thus resolving the leaks. The subgaleal fluid collections that developed after surgery were also resolved without surgical intervention. Occipital neuralgia, as seen in one patient, is a well-known complication following posterior fossa surgery [29]. These minor complications would not ordinarily warrant concern. However, the fact that they occurred predominantly in the patients undergoing duraplasty is of some significance.

Eight cases of subdural hygroma after foramen magnum decompression (FMD) with duraplasty have been reported. [12,28,29] Subdural hygroma become symptomatic 5 to 21 days after FMD in all cases, suggesting the hygroma started early after FMD. Suzuki et al; 2011 [28] reviewed postoperative subdural hygromas and reported that in four of the eight cases small CSF leak was observed at operation and the postoperative subdural hygroma was ascribed to arachnoid tear that acted as a check valve in three cases, CSF leakage ceased spontaneously soon after arachnoid bulging as if the arachnoid membrane was left intact, Suzuki et al, concluded that caution should paid if CSF leakage has occurred even if very small and the arachnoid appears intact, and they recommend wide opening of the arachnoid intraoperatively to avoid CSF divergent therapy which may aid spontaneous resolution of subdural hygroma, no subdural hygromas were reported as postoperative complication in our series.

It is difficult to draw conclusions from a series of limited size; however, there is a suggestion that patients with syringomyelia may have a higher possibility of improvement after undergoing duraplasty. Nevertheless, some patients showed a decrease in syringomyelia, with an improvement in symptoms, through bone removal alone. This improvement was associated with an increase in the size of the cisterna magna, allowing improved CSF flow and thereby leading to resolution of the syringomyelia.

It therefore seems that duraplasty provides a better chance of enlarging the size of the cisterna magna. Performing duraplasty to treat Chiari I malformation may lead to a greater decrease in concurrent syringomyelia. However, a subset of patients whose syringomyelia will decrease through bone removal alone still exists.

Recently, some authors have reported endoscopic approaches for the management of Chiari I malformation [10]. The use of an endoscope may be helpful to assist micro invasive surgical strategy for CM-I patients.

Further studies are needed in order to better characterize these patients and to determine which patients with Chiari I malformation are better served with bone decompression alone, and which patients will require duraplasty to resolve their syringomyelia.

REFERENCES


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Surgical Management of Spinal Ependymoma

Ahmed Elsayed, MD
Department of Neurosurgery, Cairo University, Egypt

ABSTRACT

Background: Intradural Tumors of the spinal cord account for 5% to 10% of all primary central nervous system tumors. Spinal ependymoma is the most common intradural spinal tumor representing approximately 2% of all central nervous system tumors. Objectives: This study aimed to evaluate the Functional outcome of surgical management of spinal ependymoma either by total or subtotal tumor resection followed by radiotherapy. Patients and Methods: This prospective study included 19 adult patients; 13 males and 6 females, the mean age was 38.4 years. Operated upon in Neurosurgery Department, Cairo university hospitals from 2011 to 2013. Preoperative symptoms were pain and/or dysesthesias, numbness, progressive weakness and urinary or sexual symptoms with an average duration of 20 month. All patients underwent surgery for spinal ependymal tumors either by total or subtotal tumor resection followed by radiotherapy. Results: Total tumor resection was done in 15 patient (78.9 %) and subtotal resection in 4 cases (21.1%) who received postoperative radiotherapy. Clinical follow up being assessed by the McCormick scale which showed that preoperatively 8 patients were in grade I, 7 patients in grade II, 3 patients in grade III and one patient in grade IV. Directly postoperative, 9 patients became in grade I and 6 patient in grade II, 2 patients in grade III and 2 patients in grade IV (P = 0.3104). Patients who showed immediate worsening in the McCormick grading experienced improvement in the grade among 6 month follow up after surgery apart from one patient showed permanent worsening. At last follow-up after 18 month postoperatively, 14 patients were in grade I, 1 were in grade II, 2 patients remained in grade III and 2 patients remained in grade IV (P = 0.2207). Patients improved or been stable in McCormick grades after surgery was 14 from 19 patients (73.7%) and one case showed permanent worsening (5.3%) in the grade. Patients received tumor resection either by total or subtotal resection followed by radiotherapy showed overall improvement in the functional outcome after surgery. Conclusions: Favorable outcome can be achieved after surgical treatment of spinal Ependymoma. Total tumor resection if feasible should be considered as the ideal treatment of spinal Ependymoma to avoid hazards of subtotal resection followed by radiotherapy which may result in less favorable outcome and potential recurrence rate on long term follow up. 

Key Words: ependymoma, dysesthesias, McCormick scale, subtotal resection

INTRODUCTION

Intradural Tumors of the spinal cord account for 5% to 10% of all primary central nervous system tumors. Spinal ependymoma is the most common intradural spinal tumor representing approximately 2% of all central nervous system tumors.1 Ependymoma is classified to myxopapillary ependymoma and subependymoma (grade I), ependymoma (grade II), and anaplastic ependymoma (grade III).19

Surgery is considered the main treatment of intradural Ependymomas,17 especially in patients who have mild or moderate neurological deficits due to the fact that complete excision of the tumor is applicable in most of the cases without worsening of the neurological condition.8 Most tumors shows well-defined margins with distinct cleavage plane which allows safe tumor excision without injuring normal surrounding spinal cord tissue.12 Radiotherapy can be applied as an adjuvant treatment for cases of subtotal resection to improve the outcome and reduce recurrent incidence.

Ependymoma of the filum terminale (EFT) is uncommon subtype of spinal cord ependymoma; it is usually of the myxopapillary type and is radioresistant. When small or medium sized tumors, it is often encapsulated by the leptomeninges that separate it from the cauda equina nerve roots.2 This capsule allow the surgeon to achieve total removal of the tumor. In contrast, large tumors are difficult to remove due to lack of capsule and sometimes due to filling of the whole lumbar cistern and totally surrounding the cauda equina roots.10

PATIENTS & METHODS

In our prospective study, 19 adult patients with intradural ependymoma were surgically treated at Neurosurgery Department, Cairo university hospitals through the period from January 2011 to February 2013. All patients underwent full history taking,
complete general and neurologic examinations. All patients were radiologically evaluated by magnetic resonance imaging (MRI). 16 were males (70.8%) and 3 were females (29.2%), the age varied from 18 to 62 years with mean age 38.4 years.

The tumor was located in the cervical spine in 9 patients, in the thoracic spine in 3 patients and in the lumbar spine in 7 cases. Preoperative symptoms were pain and/or dysesthesias, numbness, progressive weakness and urinary or sexual symptoms with an average duration of 20 month. In our study we used a modified McCormick scale (Table 1) to assess the clinical neurological outcome of the cases in which 8 patient were grade I, 7 patients were in grade II, 3 patients were grade III and one patient was grade IV. Follow-up neurologic examinations and radiological evaluation by MRI was done during 18 month after surgery to follow any recurrence or progression. In addition to have immediate MRI for cases who experienced neurological worsening.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Modified McCormick scale</th>
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<tbody>
<tr>
<td>I</td>
<td>Intact neurologically, normal ambulation, minimal dyesthesia</td>
</tr>
<tr>
<td>II</td>
<td>Mild motor or sensory deficit, functional independence</td>
</tr>
<tr>
<td>III</td>
<td>Moderate deficit, limitation of function, independent w/external aid</td>
</tr>
<tr>
<td>IV</td>
<td>Severe motor or sensory deficit, limited function, dependent</td>
</tr>
<tr>
<td>V</td>
<td>Paraplegia or quadriplegia, even w/flickering movement</td>
</tr>
</tbody>
</table>

**Surgical Techniques**

Corticosteroids and broad spectrum antibiotics were administered to all patients preoperatively. Surgical procedure was conducted under general inhalation anesthesia; after induction of anesthesia and endotracheal intubation, the patient was put in prone position. A Mayfield cranial clamp was used for cervical and upper thoracic lesions and intraoperative neurophysiologic monitoring was used. A standard midline incision was made then subperiosteal separation of the paraspinal muscles took place. After laminectomy was done, a midline dural incision was done. A midline myelotomy is performed. After internal decompression especially in large tumors, Tumor is dissected by Sharp dissection or removed en bloc if possible. Hemostasis was carried out with inspection of tumor bed for any residual tumor. Dura was tightly closed and wound was closed in layers. (Fig. 1, 2)

**Table (1):**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Modified McCormick scale</th>
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<tbody>
<tr>
<td>I</td>
<td>Intact neurologically, normal ambulation, minimal dyesthesia</td>
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<tr>
<td>II</td>
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<td>III</td>
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<td>IV</td>
<td>Severe motor or sensory deficit, limited function, dependent</td>
</tr>
<tr>
<td>V</td>
<td>Paraplegia or quadriplegia, even w/flickering movement</td>
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</table>

**RESULTS**

The study included 19 patients, 15 patient had Total tumor resection (78.9%) and 4 patients (3 cervical located and one thoracic located ependymoma) had...
subtotal resection (21.1%) and received postoperative radiotherapy. Cases who underwent subtotal tumor removal was due to invasion of the tumor in the adjacent cord tissue, the cleavage plane was not easily distinguishable and intraoperative loss of SSEPs (somatosensory evoked potentials) in the lower extremities was recorded. Therefore total removal was not attempted for the risk of poor outcome. According to McCormick scale preoperatively, 8 patients were in grade I (42.1%), 7 patients were in grade II (36.8%), 3 patients were in grade III (15.7%) and one patient was in grade IV (5.2%). Immediate postoperatively, 6 patients remained in grade I and 2 patients worsened to grade II but improved in the 6 month follow up to grade I. Three patients from grade II improved directly postoperatively to grade I, 3 patients showed gradual improvement over 6 month follow up to grade I and one patient didn’t improve. 2 patients of grade III remained in the same grade and one patient showed worsening to grade IV to be 2 patients in this grade (P = 0.3104).

Tumor specimen's Histopathological examination showed low grade ependymoma in 15 patients, ependymoma grade II in 3 patients, and anaplastic ependymoma grade III in 1 patient. Subtotal tumor resection was done in the 4 cases with ependymoma grade II and III followed by adjuvant radiotherapy. Follow-up neurologic examinations and radiological evaluation by MRI is done direct postoperatively and every six month for 18 month after surgery to follow any recurrence or progression. At last follow-up at 18 month postoperatively 14 patients were in grade I, 1 patients were in grade II, 2 patients were in grade III, 2 were in grade IV (P = 0.2207) (Table 2). There was no recurrence or increase in size in the residual cases revealed by follow up MRI spine. Patients improved or been stable in McCormick grades after surgery was 14 from 19 patients (73.7%) and one case showed permanent worsening (5.3%) in the grade. Patients received tumor resection either by total or subtotal resection followed by radiotherapy showed overall improvement in the functional outcome after surgery. Although direct postoperative and last follow up functional outcome showed improvement but this was insignificantly correlated with the preoperative outcome.

Table (2): Clinical Data of the patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Value</th>
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<tr>
<td><strong>Age(years)</strong></td>
<td><strong>Mean</strong></td>
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<tr>
<td></td>
<td>46</td>
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<tr>
<td></td>
<td><strong>Range</strong></td>
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<tr>
<td></td>
<td>18-62</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td><strong>Male</strong></td>
</tr>
<tr>
<td></td>
<td>13</td>
</tr>
<tr>
<td></td>
<td><strong>Female</strong></td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Cervical</strong></td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td><strong>Thoracic</strong></td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Lumbar/conus</strong></td>
</tr>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td><strong>Surgery</strong></td>
<td><strong>Total resection</strong></td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal tumor resection</strong></td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>McCormick grade</strong></td>
<td><strong>Preoperative</strong></td>
</tr>
<tr>
<td></td>
<td>Grade I</td>
</tr>
<tr>
<td></td>
<td>8 (42.1%)</td>
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<tr>
<td></td>
<td>Grade II</td>
</tr>
<tr>
<td></td>
<td>7 (36.8%)</td>
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<td></td>
<td>Grade III</td>
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<tr>
<td></td>
<td>3 (15.7%)</td>
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<tr>
<td></td>
<td>Grade IV</td>
</tr>
<tr>
<td></td>
<td>1 (5.2%)</td>
</tr>
<tr>
<td><strong>Postoperative</strong></td>
<td>Grade I</td>
</tr>
<tr>
<td></td>
<td>9 (47.4)</td>
</tr>
<tr>
<td></td>
<td>Grade II</td>
</tr>
<tr>
<td></td>
<td>6 (31.6)</td>
</tr>
<tr>
<td></td>
<td>Grade III</td>
</tr>
<tr>
<td></td>
<td>2 (10.5)</td>
</tr>
<tr>
<td></td>
<td>Grade IV</td>
</tr>
<tr>
<td></td>
<td>2 (10.5)</td>
</tr>
<tr>
<td><strong>Last follow up</strong></td>
<td>Grade I</td>
</tr>
<tr>
<td></td>
<td>14 (73.7)</td>
</tr>
<tr>
<td></td>
<td>Grade II</td>
</tr>
<tr>
<td></td>
<td>1 (5.3)</td>
</tr>
<tr>
<td></td>
<td>Grade III</td>
</tr>
<tr>
<td></td>
<td>2 (10.5)</td>
</tr>
<tr>
<td></td>
<td>Grade IV</td>
</tr>
<tr>
<td></td>
<td>2 (10.5)</td>
</tr>
<tr>
<td><strong>Tumor pathology</strong></td>
<td>Low grade ependymoma</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Ependymoma grade (II)</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Anaplastic ependymoma grade (III)</td>
</tr>
<tr>
<td></td>
<td>1</td>
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</table>
**DISCUSSION**

Surgery is considered the main treatment of intradural Ependymoma. The use of MRI and microscopic techniques had contributed in improving outcome of the surgical excision of spinal ependymoma. Total tumor resection should be the main goal of treatment of spinal cord ependymoma with neurological preservation. Cases with mild or no neurological deficit get benefit from total tumor resection that can be achieved with neurological preservation and lower morbidity. Subtotal tumor excision is done in tumors that shows infiltration of the adjacent spinal cord tissue which can be predicted intraoperatively by The use of SSEPs. 

In this prospective study total tumor resection was achieved in 15 cases (78.9%) and 4 patients had subtotal resection (21.1%) subtotal tumor resection was done in cases with 3 cervical located and 1 thoracic located ependymoma. Other reports as Wolfgang et al., mentioned that total tumor resection was achieved in 48 cases from 57 patients (84%) and subtotal excision in 9 cases(16%).this ratio was less in other studies like Akyurek et al. (60%), and Gomez et al. (55%).

Functional outcome in our study was assessed with McCormick scale, at last follow up: 14 patients were in grade I, 1 patients were in grade II, 2 patients were in grade III, 2 in grade IV. 14 from 19 patients (73.7%) had stable or improved McCormick grades and one case showed permanent worsening (5.3%) in the grade. These results go along with Marec et al., who found in his study that 49 of 57 patients (86%) had stable or improved McCormick grades after surgery and the permanent decrease in the grade was seen in 4 (7%) patients. After surgery, Patients who have preoperatively minor or no neurological deficits showed better functional outcome than those with preoperative deteriorated neurological status even if any of the first group showed immediate postoperative worsening they improved latter in follow up period. In our study improvement of functional outcome was achieved in patients treated with total and subtotal resection even when followed by adjuvant radiotherapy. Elisa et al. in their study which included 67 patients, total tumor excision was carried out in 55 of them showing better outcome than partial tumor resection on long term follow up period among 23 years which was longer than our follow up period. Chang et al. reported that patients with total resection have a significantly longer progression-free survival than those who had subtotal excision and adjuvant radiotherapy. Philippe et al., mentioned that Complete removal of spinal ependymoma can be achieved in the majority of patients (92%), with good neurological outcome in patients with normal neurological examination or with mild sensory-motor deficit. There is a global debate in usage of radiotherapy in the treatment of spinal ependymoma. Most authors recommend radiotherapy after a subtotal tumor resection, for disseminate and anaplastic ependymoma. In our study adjuvant radiotherapy was given to patients with subtotal tumor resection, their pathology was ependymoma grade II and anaplastic III with no progression on follow up period. Akyurek et al. mentioned that radiotherapy after surgery has better progression free survival rates than surgery alone. On the other hand Abdel-Wahab et al. found in his series...
that Postoperative radiotherapy for ependymomas was not associated with better tumor control. Quigley and colleagues could not prove a statistical difference in Progression-free survival in the portion of their cohort who underwent STR with radiotherapy.

There was no recurrence of tumor in our study which may be interpreted with lack of long period follow up which is recommended by many authors even after use of radiotherapy to detect any tumor recurrence or progression. In Wolfgang et al., study conducted in 10 years reported that the recurrence/tumor progression rate was low (9%). Low rates of tumor recurrence reflect developing treatment modalities for spinal ependymoma either total resection or subtotal excision followed by radiotherapy. We believe that favorable functional outcome can be achieved by total or subtotal tumor excision in spinal ependymoma, total tumor excision should be preferable to avoid potential recurrence rate and complications of radiotherapy after partial excision.

CONCLUSION

Favorable outcome can be achieved after surgical treatment of spinal Ependymoma. Total tumor resection should be the main goal in treatment of intramedullary spinal ependymoma, if possible, which favors for better functional outcome especially on the long term. If not, subtotal excision followed by radiotherapy is to be considered.

REFERENCES


Reliability of Postoperative Multi-slice Computed Tomography in Assessment of Pedicle Screw Placement in Thoracic and Lumbar Spinal Fixation

Akram M. Awadalla¹, Inas M. El Fiki ² and Fatma Zaiton²

Neurosurgery¹ and Radiology² Department,
Prince Salman Military Hospital (KSA)¹ and Zagazig University (Egypt)¹,²

ABSTRACT

Background: Transpedicular instrumentation procedure has become an established method for stabilization of the thoracic and lumbar spines. Since their introduction, the accuracy and complication of placing pedicle screws has been the subject of many reported studies. Objective: To evaluate the reliability of three-dimensional (3-D) volume rendering computed tomography (CT), in postoperative assessment of pedicle screw placement. Patients and Methods: Ninety-eight patients with previous spinal fixation surgery were included. All inserted screws were evaluated postoperatively within the first week using CT. Degree of misplacement and difference between CT images were recorded. Results: 76, 68 and 39 misplaced screws were detected in 3-D reformatted image, coronal reconstruction and axial CT images respectively. Dorsal spine had higher rate of violation 46 (9.95%) with the highest rate at T4 (12.8 %) comparing it with lumbar 32 (6.9 %). Statistically significant differences were found between lateral and medial violation (P value=0.03), between findings of CT-3D reformatted and axial image (P = 0.04), and also in detecting end plate perforation and anterior vertebral encroachment in different CT images (P value=0.013). Sensitivity for 3-D reformatted image and axial image compared with surgical finding in six revised screws was 100% and 95.8 % and specificity 100% and 89.7 % respectively. Highly momentous agreement reported with Kappa coefficient=0.95 ± <0.001. Conclusion: The vertebral body and the pedicle are 3-D structures. Therefore, we have to study them as they are. The postoperative evaluation of pedicle screw using CT-3D reconstruction was a reliable method and unveiled the deficiencies in conventional axial CT.

Key Words: multi-slice computed tomography, thoracic,lumbar, pedicle screw.

INTRODUCTION

Transpedicular instrumentation procedure has become an established method for stabilization of the thoracic and lumbar spines.(15,33,37)

Nowadays transpedicular fixation is popularly and successfully used for spine stabilization in the setting of wide range of spinal disorders as degenerative disc disease, traumatic, infectious, neoplastic and malformedive pathologies associated with axial instability.(9)

Since their introduction, the accuracy and complication of placing pedicle screws has been the subject of many reported studies.(10,48)

Pedicle screws that perforate the pedicle cortex may increase the risk of dural tearing, neural damage, and vascular or visceral complications. Moreover, such pedicle screw malposition may result in loss of fixation, especially if it occurs at the lower end of the construct. Therefore, proper placement of pedicle screws is important not only for the prevention of neurological injury but also for the maintenance of long-term spinal stability.(1,18,43)

Postoperative imaging is typically performed to assess the progress of osseous fusion, to confirm the correct positioning and the integrity of instrumentation, to detect suspected complications (e.g., infection or hematoma), and to detect new disease or disease progression.(8)

Plain radiography most commonly used in the assessment of pedicle screw's placement, although CT (Computed tomography) is reported to be more accurate.(33)

The quality of CT images may be severely affected by metallic artifacts due to the implants. Titanium made screw has been recently used, and it causes fewer artifacts due to lower x-ray attenuation compared stainless steel screw.(8)

Patient movement as well may be resulting in artifacts, which affect the image, however, the introduction of high-speed multi-slice CT has been reduced the possibility of this type of artifact. Also image reconstruction using multi-planar reformate (MPR) and Three dimensional volumes rendering (3D-VR) technique, often results in higher-quality images that are more useful clinically than axial images alone.(26,31)

This study was intended to evaluate the diagnostic value of postoperative CT- 3D (VR) reformatted image for assessment of pedicle screw trajectory in dorsal and lumbar spine comparing it with axial and coronal reconstruction images.
PATIENTS & METHODS

This retrospective study including all patients who underwent thoraco-lumber fixation between June 2010 and June 2012 at Prince Salman Military Hospital were included. To avoid any bias, the unidentified raw material sent on CDs for radiological assessment by two independent observers at Zagazig university-Egypt.

Inclusion criteria: All of the patients had posterior transpedicular fusion procedures because of dorsolumber fractures, spondyloolisthesis, severe lumbar instability, spinal stenosis, and failed spinal surgery. Exclusion criteria including patients with scoliosis and severely osteoporotic patients.

Ninty eight patients were met the eligibility to participate in this study (56 male and 42 female), their age ranged from 19 to 65 years (mean age 28±5).

All operations were performed by the same neurosurgeon (first author) using the same technique and all implants used were made of titanium.

Postoperative computed tomography control was done for all patients within a period of 1-8 days. This study was approved by local ethical committee.

Surgical technique

We used a midline skin incision over the segments requiring fusion and bluntly dissected the paravertebral muscles subperiostially, after that the transverse processes were exposed.

Using the Roy-Camille technique the most widely accepted procedure by spinal surgeons worldwide. The insertion point is the midpoint of the line between the transverse processes as it crosses the top of the pedicle. The direction of the screws follows the axis of the pedicle. It is slightly oblique towards the midline. Its angular value is variable according to the individual. At S1, the entry point is at the infero-lateral margin of the basis of the superior articular process of the sacrum. Unlike, the large ovoid lumbar pedicle, the cross-sectional morphology of a single thoracic pedicle is widely variable especially in the coronal plane for the upper and mid-thoracic levels. We counted on real time image intensifier especially A/P image as intraoperative guide. After the initial perforation, internal pedicle palpation by ball tip and gearshift probe, as well as tapping, are utilized in order to verify the presence of possible pedicle violations. After the placement of pedicle screws the final construct is connected with rods, 3-D heads, and location caps. Cross link was used in 45 systems(46%). Bone graft is then placed outside the pedicle-screw-rod assembly. Under real-time image intensifier use, insertion was completed at an angle of the sagittal plane. Spinal reduction was performed by distraction force applied on both tail ends of the upper and lower pedicle screws after rods were connected and guided by intraoperative imaging to reduce spinal kyphosis and retropulsed burst fragments. Both final lateral and anterior/posterior images of the implanted system were received by the image intensifier before completion of the operation.

Radiographic examination

All patients were scanned using multislice 64 slice CT imaging (Light Speed VCT, GE Healthcare, Milwaukee, WI). Image acquisition was performed in helical mode, in crano-caudal direction with the patients supine. The imaging series consisted of (3mm slices) 0.6-2 mm-thick CT sections (collimation 8×2.5 mm) at 2-mm intervals with a pitch of 0.875:1 and acquisition parameters of 120 kVp and 60 mAs.

Image reconstruction

The raw data were used to reconstruct axial and coronal multiplanar reformation (MPR) with a field of view adequate for visualization of the spine. Reconstructions were performed in both soft tissue and bone windows. A dedicated post-processing workstation (Advantage Windows Volume share 4.5, GE Medical System, Milwaukee, WI, USA) was used to obtain further image processing as volume rendering (VR) to obtain 3D images. The reformatted 3D images were cleared from any metal artifacts so that the whole length of the screw was clearly visible and easily evaluated.

Image interpretation:

The obtained unidentified CT image were reviewed for affected level, inserted screw, presence of screw related or non screw related complication on two separate sessions (1-2 month apart) by two independent radiologists who were unaware of the clinical presentation of the patients.

The position of the screw within the pedicle was assessed according to classification previously published in the literature. Each screw was examined for:

1- Error in insertion of the screw in relation to the pedicle angle.
2- Position of the screw within the pedicle. The screw was considered as (in) if it was correctly positioned.
within the pedicle, or (out) if it was malpositioned and a portion of the screw penetrated through the cortex. Screw displacement was measured in millimeters using the scale on the CT image and classified according to the distance that the edge of the screw thread extended outside the pedicle cortex and graded into Grade 0 is no apparent violation of the pedicle. Grade I <2 mm perforation of the pedicle with one screw thread out of the pedicle. Grade II between 2 and 4mm or perforation of the pedicle with half of the diameter of the screw outside the pedicle. Grade III > 4 mm or complete perforation of the pedicle. 

3- Presence of end plate perforation or vertebral extrusion.

4- Error in direction of screw penetration which described as lateral, medial, cranial or caudal.

Correlation between the CT finding and the clinical data was done. All patients were followed clinically and radiologically for at least 3 months, the incidence of complication, patient satisfaction, response of the existing pain, development of neurological pain or deficit, need for revision operation was all reported.

Statistical analysis

Data were checked, entered and analyzed by using SPSS version 20; Data were expressed as numbers and percentage. Chi-square($\chi^2$) or Fisher exact test were used when appropriate, Kappa agreement was used. P<0.05 was considered statistically significant.

RESULTS

Postoperative CT evaluated a total number of 462 screws inserted in 98 patients. Osteodegenerative spinal instability was the most common encountered in our patients (45.9%), other indication for fixation and incidence of screw per indication was listed in (Table I).

<table>
<thead>
<tr>
<th>Indication</th>
<th>No of patient</th>
<th>No of screw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traumatic</td>
<td>30 (30.6%)</td>
<td>146 (31.6%)</td>
</tr>
<tr>
<td>Degenerative</td>
<td>45 (45.9%)</td>
<td>202 (43.7%)</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>23 (23.5%)</td>
<td>114 (24.7%)</td>
</tr>
<tr>
<td>Total</td>
<td>98 (100%)</td>
<td>462 (100%)</td>
</tr>
</tbody>
</table>

In overall results the higher rate of fixation was seen in L5 (48 screws). Most of the implanted screws were found to be correctly positioned within the pedicle, out of the 462 inserted screws, 76 (16.5%), 63 (13.6%) and 39 (8.5%) screws were found to be malpositioned on 3-D reformatted image, coronal reconstruction and axial CT images respectively.

The dorsal pedicle shows higher rate of screw violation when compared with lumber one measuring 46 (9.95%), 32 (6.9%) respectively. The spinal levels with the highest incidence of cortical breach were T4 (12.8%) followed by L5 (10.3%). Chart one shows number of screws inserted in each vertebra and incidence of screw breaches.

Chart I: Number of screws inserted and screw violation in each level.

Lateral screw violation was more detected than the medial one on all CT images with significant difference (P value=0.03).

The coronal and 3-D reformatted image had the advantage in assessing screw violation in cranial and caudal direction as well as evaluation of disc space penetration.

End plate perforation and anterior vertebral encroachment were more obvious in reformatted image than axial image which is statistically significant (P value=0.013).
Table II: Summary of location of perforation of the misplaced screws; comparison of axial, coronal and reformatted three-dimensional studies.

<table>
<thead>
<tr>
<th></th>
<th>Axial</th>
<th>Coronal</th>
<th>3-D reformatted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lateral</td>
<td>Medial</td>
<td>Total</td>
</tr>
<tr>
<td>Pedicle penetration</td>
<td>22</td>
<td>11</td>
<td>33</td>
</tr>
<tr>
<td>Grade I</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Grade II</td>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Grade III</td>
<td>8</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Endplate penetration</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Anterior encroachment</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc space penetration</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>13</td>
<td>39</td>
</tr>
</tbody>
</table>

Radicular pain and neurological deficits were observed in 9 (9.2%) patients. Only 4 (4%) patients were in need for revision operation while the other 5 patients responded to conservative treatment. Of the 6 screws needed revision 3 (50%) were of Grade I medial, 1 (12.5%) Grade III lateral and 2 (25%) Grade III medial. In all patients the misplaced screw was removed and a new one was correctly placed using the same entry point with new proper direction. However, two screws were replaced with sublaminar hooks. No spinal cord, dural, vascular, or pulmonary injuries have been reported.

There was no significant relation between development of complication, level and the cause of operation. Also no significant relation between grade of screw displacement and incidence of complication or revision as most of the patients with misplaced screw were completely asymptomatic. However significant correlation was noted for medial displacement of the screw and severity of complication and rate of revision (75% of revised cases).

Sensitivity of CT images in evaluating screw position compared with operative finding in 6 revised screws shows sensitivity of 100% and specificity of 100% and 88.7% for 3-D reformatted image and axial image respectively.

Comparing patient's satisfaction with radiological findings revealed no significant relation between severity of screw violation and patients complaining.

A statistically significant difference was obtained on comparing findings of both axial CT and 3-D reformatted imaging, (P = 0.04).

Interobserver agreement between the two radiologists showed no significant difference noted between the findings obtained from the postoperative CT images.

Kappa coefficient = 0.95 ± 0.001 highly significant agreement.

FIG. II: (A) axial CT image and (B) coronal CT reconstruction show correct position of the screws within the pedicles. (C) Reformatted three-dimensional images show excellent views of the skeletal anatomy and correct position of the inserted implants.
FIG. III: (A) axial CT image of L1 and (B) axial 3-D CT image show good position of the screws. However, the Rt. One showed < 2 mm pedicle violation (Medio-lateral evaluation). (C) Coronal CT reconstruction shows end plate penetration by the screw at L1 level and (D) Reformatted 3-D images of the full skeleton show downwards displacement of the inserted screws at L1 and L2, penetrating the end plates with anterior vertebral encroachment.

FIG. IV: (A) axial CT image shows the right screw looks contained in the right pedicle. However, the rest of the screw looks at the right edge of vertebral body. In axial slice (B) the rest of the Rt. screw looks inside the vertebral body entirely. (C) 3-D reformatted CT images show the Rt. screw violated the pedicle laterally and the rest inside vertebral body. The Lt. one is ideal.
DISCUSSION

Pedicle screws have been used in posterior spinal fixation since first reported by Boucher\(^{(15)}\). In 1959 and subsequently popularized by Roy-Camille et al.\(^{(32)}\). Today, pedicle screws are routinely used throughout the vertebral column because of their proven effectiveness in stabilizing all 3 columns of the spine. However, pedicle screws remain technically demanding to place, particularly in the thoracic region because of the smaller size and more complex morphology of thoracic pedicles.\(^{(28)}\) Efforts to study optimal placement and evaluate safety of pedicle screw instrumentation in the spine have led to numerous published studies.\(^{(37)}\)

Specific interests in the accuracy and precision of pedicle screw placement have been driven by safety concerns, including the risk for neurological complications caused by violations to the spinal canal and the possibility for vascular and/or visceral injury.\(^{(12,28)}\)

The anatomic studies performed in the last two decades, showing the complex morphometry and three-dimensional anatomy of the thoracolumbar pedicles.\(^{(27,44)}\)

In spite of improvement of surgical techniques and increased real-time use of the image intensifier, the improper placement of pedicle screws may occur which is considered the most commonly reported complication.\(^{(12,27,44)}\)

The overall rate for screw violation reported in the literature were ranged between 0-42\%.\(^{(28)}\)

The wide variation in rate of screw violation was referred to many causes as indication for surgery, levels of instrumented spine, variation in type of population studied (in vivo or in human cadavers), the operative technique and the intraoperative assisted guidance, the surgical experience as well as the method of postoperative evaluation.\(^{(12)}\)

It is still a matter of debate, but it seems that the addition of fluoroscopy modestly improves the accuracy of screw placement, especially in the upper and middle thoracic spine.\(^{(25,33)}\)

In fact, in the two largest series of thoracic pedicle screws placed with fluoroscopic guidance alone, the authors noted a low incidence of neurological injury in spite of higher rates of pedicular violations.\(^{(20,25)}\)

Although many spine surgeons consider anteroposterior and lateral plain X-rays as adequate imaging modality for the assessment of the final positions of pedicle screws, it has been well established from late 80s that these imaging methods may lead to unacceptably high rates of false-positive and false-negative evaluations.\(^{(19)}\)

Roentgenogram assessment has been studied and reported to be unreliable as the sole means of evaluating pedicle screw placement.\(^{(8)}\)

The sensitivity and specificity of Plain x-ray were low when compared with postoperative CT.\(^{(6,8,19)}\)

Advances in CT imaging technology have made CT accepted to be a gold standard technique for postoperative screw evaluation. However, the CT slices can show the proximity between the screw and bony or neural elements only in two dimensions. Moreover, metallic artifacts and the difficulty of following the screw trajectory between the slices are problematic in axial CT images.\(^{(40)}\)

Rate of screw violation in our series was found to fall in the range of the incidence reported in the literature, we found 16.5% screw breach from the all inserted screws. Our results were lower than that
previously described in some studies as by Laine et al.\(^{(22)}\) who noted a screw malposition rate ranged from \(28.1\%\) to \(39.9\%\) in his clinical studies also Lotfinia et al.\(^{(16)}\) reported that faulty placement of the screw was seen in \(35.22\%\) of their cases, and Castro et al.\(^{(7)}\) performed a study of 30 patients with 131 screws placed showed cortical penetration in \(40\%\) of his patients, these differences may be due to: in our study, all included factors have been standardized as much as possible. In all of our cases, surgery was performed by the same surgeon, at a single institution, using the same fusion technique after preoperative measurement, the same implant and the evaluation was done by two independent radiologists using the same rules. Moreover, we excluded patients with spinal deformity, severely osteoporotic spine and who had undergone previous spinal fixation surgery.

On the other hand, our rate was more than that reported in other literature, as many authors\(^{(2,9,28,43)}\) considered placement inadequate in all screws with errors of > 2 mm and they did not include this group in their rate of misplacement, also in other studies as in a meta-analysis done by Schizas et al.\(^{(34)}\) from 1966 until 2006 (130 studies involving a total of 37,337 PSs inserted) they found a mean misplacement rate of 8.7% and by Lonstein et al.\(^{(24)}\) in their study of 4790 implanted screws, reported a misplacement rate of 5.1%. This attributed to that they use plain radiographs as method of post operative assessment which appear to be underestimating when compared to CT scan assessment.\(^{(3)}\)

The difference between axial and multi-slice images illustrates the inadequacy of the axial images. These results strongly suggest the requirement for multi-slice imaging. Multislice 3-D reformatted image easily showed the full length of the screw with lack of metallic artifact with accurate evaluation of the relation between the screw and the neural elements.\(^{(38)}\)

The reconstructed images from these two planes, axial or coronal, are useful and reliable in evaluating pedicle screw placement success. The use of both planes is advocated for better assessment of pedicle screw placement success.

Only a few studies have evaluated multiple CT image planes in reporting placement success. As pedicle screw placement is a three-dimensional (3-D) issue, addition of the coronal plane may provide important direction-based information (e.g., cranial or caudal perforations) for the assessment of screw placement.\(^{(13,16,40,41)}\)

Most of the studies published in the literature, use only two dimensional (2-D) axial CT images for post operative evaluation of the 3-D nature of the pedicle screw. The addition of new 3-D VR or coronal MPR techniques can provide valuable information in evaluating successful placement of the pedicle screw.\(^{(4,7,14,19,21,40,38)}\)

In our study, axial image could detect only 39 (9.8%) out of the misplaced screws seen at coronal reconstruction 63 (13.6%) and 3-D reformatted image 76 (16.5%), these were statistically significant (P value= 0.004), our results agree with Schizas et al.\(^{(34)}\) in their study compare axial CT images with coronal reconstruction and found incidence of violation was 23.3% for axial and 30% for coronal images, also in the series of Çelik et al.\(^{(38)}\) he compared the axial images with 3-D reformatted images and they found lower incidence for axial (9%) in comparison to that of 3-D reformatted images (13.1%) and they attributed that to the fact that in reformatted images not only medial and lateral screw placement accuracy is evaluated, but also cranial and caudal placement especially in the coronal cuts, also the presence of metallic artifacts in axial images alter the image interpretation with difficulty of following the screw trajectory between the slices.

The difference between 3-D reformatted image and coronal reconstruction may be due to evaluation of screw position in the sagittal plane as well as the full length of the screw is easily evaluated in 3-D reformatted image.\(^{(38)}\)

When compared the anatomical aspect of thoracic and lumbar spine, the pedicle in thoracic spine is smaller, with increasing variability in its anatomy, this explains why the incidence of screw breach was considerably more frequent in the thoracic than the lumbar spine\(^{(3,17,31)}\) in our study, the rate of screw violation was higher in dorsal spine (9.95%) in comparison with lumbar one (6.9%), this in accordance with Parkers et al.\(^{(35)}\) and Rodrigues et al.\(^{(38)}\) who reported same higher rate of screw violation in dorsal than lumber spines.

The incidence of pedicle violation reported in the literature seems to correlate inversely with the size of the pedicle. In morphometric studies, the transverse diameter of the pedicle diminishes from T1 in caudal direction, presenting the lower value at the mid thoracic region (T6 and T7). From T8 to L5, the pedicle diameter grows progressively and the rate of pedicle violation diminishes accordingly.\(^{(13,16,40,41)}\)

We found the highest incidence of screw cortical breach was at T4 (4.1%) this also described by Parker et al.\(^{(35)}\) who reported highest rate of cortical breach at T4 and T6 and he mentioned that this was not surprising because the pedicles of these vertebrae are relatively small to accept the full diameter of the screw. Pedicle screw placement is often limited by the diameter of the pedicle. Coronal images allow for full visualization of this limiting dimension, making them a valuable additional assessment tool along with the currently widely used axial CT images especially, for the dorsal pedicles.
In contrast to the lumbar spine, considerable variation may exist among thoracic vertebrae, either in terms of the relationship of the transverse process and the axis of the pedicle or in the angle of the pedicle to the vertebral body. Because of the variability in these individual parameters, "free-hand" pedicle instrumentation in the upper and midthoracic spine based exclusively on anatomic landmarks may be imprecise and eventually lead to unacceptable rates of misplaced screws. In fact, both clinical and cadaveric studies have shown that about 15% to 50% of thoracic screws placed using "free-hand" technique may violate the pedicular cortex.\(^{(38)}\)

In the thoracic spine, the benefits of pedicle screws have been tempered by its potential risks, such as, spinal canal violation, pedicle fracture, nerve root compression, and vascular lesions. Furthermore, the narrow and inconsistent shape of the thoracic pedicles, especially in spinal deformity, makes their placement technically challenging.\(^{(39)}\)

Pedicle screw placement in the thoracic spine presents a unique challenge. Unlike the lumbar pedicle, there is little room for error in the small and three-dimensional complex thoracic pedicles. Medial errors are less forgiving in the thoracic spine because there is less mobility of the spinal cord at this level in comparison to the nerve roots in the cauda equina. Lateral perforations of the pedicular cortex are potential threats to the pleural cavity, great vessels and esophagus, mainly in the upper and middle thoracic levels.\(^{(25)}\)

The majority of breaches noted were in lateral (61.3%) than medial direction, this was in accordance with Lotfina et al, parker et al, and Gonzalez-Cruz et al\(^{(16,35,10)}\) they found higher rate of lateral cortical breach, and they were referred that due to the surgeon choose a more lateral trajectory away from the thicker medial cortical wall of the pedicle as well as the desire of the surgeon to avoid potential injury to the spinal cord.

Guven et al. investigated the accuracy of in vivo CT scanning in the placement of pedicle screws in thoracic and lumbar spines. The screws were inserted according to the Roy-Camille technique without fluoroscopy. The authors classified the screw position according to cortical perforation or horizontal and lateral misplacement. There were 5% lateral, 3% medial, and 2% superior cortical misplacements observed without serious screw-related complications.\(^{(41)}\)

Neurologic complications and nerve root irritations reported in the literature with a range from 0.2% to 11%\(^{(26)}\), in accordance with this study, we reported 9% of neurological pain and deficits in our patients, this was lower than that reported by Lotfina et al.\(^{(16)}\) he reported 15.09% of neurological pain, the higher incidence in last study due to they include all patients with sensory or motor symptoms in spite of the presence or absence of real neurological deficits.

In a series which evaluated the rates of medial violation of the screws in the thoracolumbar transition, only patients with violations of more than 6 mm presented neurological deficits, suggesting that, between T10 and L4 exists a "safety zone" which tolerates medial violations up to 4 mm. This was attributed to the larger diameter of the pedicle at this region as well as larger diameter of the spinal canal.\(^{(29)}\)

Not all patients with neurological pain and deficits need revision operation\(^{(16)}\), this strongly in agree with our study where only 5 patients need revision with revision rate of 1.2 % of the inserted screw, this nearly agree also with Parker et al.\(^{(35)}\) who reported 0.8% revision rate.

No definitive dural, vascular, or pulmonary injuries were reported in our patients, in accordance with Rodrigues et al and Reidy et al.\(^{(30,29)}\)

There was interobserver agreement comparing results obtained from the examined different image with excellent \(\kappa=0.95\), our results was comparable to Kosmopoulos et al.\(^{(40)}\) who report a perfect value \((\kappa=0.90)\) for interobserver agreement strength in comparing readings between observers.

**CONCLUSION**

The vertebral body and the pedicle are 3-D structures. Therefore, we have to study them as they are. The preoperative measurement and the postoperative assessment of vertebral body and the pedicle in 2-D axial CT is inadequate. We believe adding another third dimension particularly; the coronal of the dorsal spine will help minimize the screw violation and will improve the outcome. We will try in our future work to study 3-D anatomy of complex morphometry of thoracic pedicle to improve our results.

**REFERENCES**


28. Oliver P. Gautschi, Bawarjan Schatlo, Karl Schaller, and Enrico Tessitore: Clinically relevant complications related to pedicle screw placement in...
Anterior Cervical Corpectomy; Evaluation of the Outcome

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Neurosurgery Department, Banha University

ABSTRACT

Background: Anterior cervical surgery now represents one of the most frequently performed spinal procedures. Although a majority of these procedures are localized to the intervertebral disc space, removal of a vertebra or several vertebrae may be indicated if the site of epidural compression extends beyond the level of a disc space. Objectives: The aim of this work is to evaluate the clinical and radiological outcome of the anterior cervical corpectomy in the management of different lesions of the cervical spine. Patients and Methods: This is a retrospective study included 30 patients underwent cervical corpectomy for the treatment of trauma (18 cases), degenerative spondylitic disease (8 cases), infection (three cases) and ossification of posterior longitudinal ligament (one case). Twenty one patients underwent one-level corpectomy and nine patients underwent two - levels corpectomy. Results: Patients’ ages ranged from 18 to 65 years (mean 37.4 years); 17 patients were males. According to Odom’s criteria, the results were excellent in 5 patients, good in 8 patients, and fair in 10 patients at the 1-month follow-up. At the last follow-up; the results were excellent in 6 patients, good in 13 patients, fair in 6 patient and poor in five patients. Conclusion: Advances in surgical techniques and spinal stabilization methods have expanded the role of corpectomy for the management of various degenerative, traumatic or infectious disorders of cervical spine.

INTRODUCTION

The principal goals in the surgical treatment of cervical spine injuries are: stabilisation of the spine, decompression of the spinal cord and facilitation of rehabilitation. When the extent of the epidural compression extends beyond the level of the disc space(s), however, removal of the adjacent vertebrae may be necessary to achieve an adequate decompression of the neural elements. Anterior cervical corpectomy is used to treat a range of injuries, degenerative disorders, tumours, ossification of the posterior longitudinal ligament (PLL), infectious disease, and other processes that involve the cervical spine.

The use of autologous iliac crest bone, once considered the graft material of choice, has been questioned because of its harvesting-related morbidities. One alternative to autologous iliac crest bone has been allograft bone, but in many studies, it has not been demonstrated to yield comparably high fusion rates, although this point remains controversial. More recently, the placement of anterior cervical cages for reconstruction after discectomies and corpectomies has been described.

The aim of this work is to evaluate the clinical and radiological outcome of the anterior cervical corpectomy in the management of different lesions of the cervical spine.

PATIENTS & METHODS

Study design: Between January 2007 to January 2012 a total of 30 patients (17 males and 13 females) admitted and surgically treated for cervical spine lesion. All patients underwent anterior cervical corpectomy. Data were collected prospectively and analyzed retrospectively. Preoperative assessment: Patients were clinically evaluated for myelopathy using the modified Japanese Orthopaedic Association (JOA) Scoring system (table 1). Anterior - Posterior (AP) and lateral radiographs, Magnetic Resonance Imaging (MRI) scan of cervical spine was carried out in all patients. Computerized Tomography (CT) scan of the spine was carried out to study bone detail and type of injury in 22 patients.

<table>
<thead>
<tr>
<th>Score</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor dysfunction score of the upper extremities</strong></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Inability to move hands.</td>
</tr>
<tr>
<td>1</td>
<td>Inability to eat w/ a spoon, but able to move hands.</td>
</tr>
<tr>
<td>2</td>
<td>Inability to button shirt, but able to eat w/ a spoon</td>
</tr>
<tr>
<td>3</td>
<td>Able to button shirt w/ great difficulty</td>
</tr>
<tr>
<td>4</td>
<td>Able to button shirt w/ slight difficulty</td>
</tr>
<tr>
<td>5</td>
<td>No dysfunction</td>
</tr>
<tr>
<td><strong>Motor dysfunction score of the lower extremities</strong></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Complete loss of motor &amp; sensory function</td>
</tr>
<tr>
<td>1</td>
<td>Sensory preservation w/o ability to move legs</td>
</tr>
<tr>
<td>2</td>
<td>Able to move legs, but unable to walk.</td>
</tr>
<tr>
<td>3</td>
<td>Able to walk on flat floor w/ a walking aid (cane or crutch)</td>
</tr>
<tr>
<td>4</td>
<td>Able to walk up and/or down stairs w/ hand rail</td>
</tr>
<tr>
<td>5</td>
<td>Moderate to significant lack of stability, but able to walk up and/or down stairs w/o hand rail.</td>
</tr>
<tr>
<td>6</td>
<td>Mild lack of stability but walks w/ smooth reciprocation unaided</td>
</tr>
<tr>
<td>7</td>
<td>No dysfunction</td>
</tr>
<tr>
<td><strong>Sensory dysfunction score of the upper extremities</strong></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Complete loss of hand sensation.</td>
</tr>
<tr>
<td>1</td>
<td>Severe sensory loss or pain.</td>
</tr>
<tr>
<td>2</td>
<td>Mild sensory loss</td>
</tr>
<tr>
<td>3</td>
<td>No sensory loss</td>
</tr>
<tr>
<td><strong>Sphincter dysfunction score</strong></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Inability to micturate voluntarily</td>
</tr>
<tr>
<td>1</td>
<td>Marked difficulty w/ micturation</td>
</tr>
<tr>
<td>2</td>
<td>Mild-to-moderate difficulty w/ micturation</td>
</tr>
<tr>
<td>3</td>
<td>Normal micturation</td>
</tr>
</tbody>
</table>

Operative Technique:

After endotracheal intubation and induction of general anesthesia, the patient is placed supine. The author prefers to operate from the patient's right side, the benefits of improved access for the right-handed surgeon outweigh the risks of a right-sided approach.

A transverse skin incision is preferred, the skin incision crosses the midline. Deinsertion of the Platysma muscle is followed by sharp dissection of the facial planes of the neck. An avascular plane is developed between the sternocleidomastoid muscle and carotid artery laterally and the trachea and esophagus medially. The carotid sheath should be palpated early in this dissection to ensure its lateral retraction. Palpation can be used to identify the cervical spine and the prevertebral fascia swept aside using a cottonoid pledget. Orientation to the vertebral midline is obtained by noting the position of the medial borders of the two longus colli muscles. The appropriate spinal level is confirmed by intraoperative radiographs. After satisfactory exposure and localization, the medial borders of the longus colli muscles are elevated. This dissection should extend beyond the rostral and caudal ends of the proposed decompression site. The added length of this dissection will allow for optimum seating of a self-retaining retractor, limiting the pressure placed on the surrounding soft-tissue structures lying more anterior. The lateral dissection of the longus colli at any level, however, should be limited to minimize the potential of inflicting an injury on the underlying vertebral artery. Excessive lateral dissection of the longus colli muscles may also result in injury to the
adjacent sympathetic chain, leading to development of a unilateral Horner syndrome. Self-retaining retractor with sharp blades are placed beneath the medial aspects of the longus colli muscles. A second set of retractors can be positioned perpendicular to the first two blades to allow rostrocaudal exposure. After placement of a retractor, the anterior longitudinal ligament is incised. Using curettage and pituitary forceps, the intervertebral discs above and below the corpectomy level are removed. The initial bone excision (anterior half of each vertebra) can be performed using a bone rongeur. This bone can be saved and used later during the reconstruction and fusion process. The remainder of the bone resection is performed using a high-speed drill, preferably under an operative microscope. A nerve hook can be used to make an initial opening through the PLL. A 1-mm Kerrison is then used to incise the lateral margins of the PLL. The remnant of the posterior longitudinal ligament is identified and dissected away microscopically. When completed, the corpectomy trough should measure approximately 15 to 16 mm in width. This ensures a thorough decompression across the entire epidural space. Having satisfactorily decompressed the neural elements, a bone graft is taken from the right iliac crest. The mortises in the rostral and caudal vertebral bodies are then prepared with the high-speed air drill, and the harvested bone graft is fashioned to fit. The bone graft is tapped into position, and radiographic evaluation is performed to assess adequate placement. In 9 patients a mesh cage filled with the bone graft was used. Following placement of the bone graft, a cervical unicortical locking plate is placed. After surgery, a hard neck collar is prescribed for 12 weeks.

Follow up:

Follow-up evaluations were performed at 1, 3 and 6 months after operation, at which time the progress of the fusion and the neurological status of the patient were documented. Fusion was defined as the presence of crossing trabeculae from the adjacent vertebral bodies to the bone graft and the absence of movement with dynamic (hyperflexion and hyper-extension) radiographs. The neurological assessment score of the last neurological examination was used as the measure of final outcome.

RESULTS

The present study included thirty patients who underwent cervical corpectomy surgery. Patients’ ages ranged from 18 to 65 years (mean 37.4 years); 17 patients were male. The distribution of the cervical segments operated on is shown in Table (2).

<table>
<thead>
<tr>
<th>TABLE 2: Patient criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesions</td>
</tr>
<tr>
<td>trauma</td>
</tr>
<tr>
<td>Degenerative spondylitic disease</td>
</tr>
<tr>
<td>Ossification of posterior longitudinal ligament</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Included cervical segments:</td>
</tr>
<tr>
<td>Single</td>
</tr>
<tr>
<td>Double</td>
</tr>
<tr>
<td>Included cervical level:</td>
</tr>
<tr>
<td>C3</td>
</tr>
<tr>
<td>C4</td>
</tr>
<tr>
<td>C5</td>
</tr>
<tr>
<td>C6</td>
</tr>
<tr>
<td>C7</td>
</tr>
<tr>
<td>Fusion material</td>
</tr>
<tr>
<td>Iliac bone</td>
</tr>
<tr>
<td>Cage</td>
</tr>
<tr>
<td>Plate</td>
</tr>
</tbody>
</table>

Clinical outcome:

The mean preoperative JOA score was 9.1 (range, 6-13) which increased to 12.0 (range, 6-15) at the 1-month follow up and further to 14.2 (range, 6-17) at the last follow-up. According to Odom’s criteria (table 3)\(^{(17)}\), the results were excellent in 5 patients, good in 8 patients, and fair in 10 patients at the 1-month follow-up. At the last follow-up, the results were excellent in 6 patients, good in 13 patients, fair in 6 patient and poor in five patients.

Table (3): Odom’s criteria\(^{(17)}\)

<table>
<thead>
<tr>
<th>Excellent</th>
<th>All preoperative symptoms relieved: abnormal findings improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Minimal persistence of preoperative symptoms: abnormal findings unchanged or improved</td>
</tr>
<tr>
<td>Fair</td>
<td>Definite relief of some preoperative symptoms: other symptoms unchanged or slightly improved</td>
</tr>
<tr>
<td>Poor</td>
<td>Symptoms and signs unchanged or exacerbated</td>
</tr>
</tbody>
</table>

Radiological outcome:

There was no case of cervical instability, instrument break down, or fusion failure during follow-up period.

Complications:

A single death (3.3%) was reported in which the patient was found in cardiopulmonary arrest during the postoperative hospital stay unrelated to surgery. Postoperative transient hoarseness and dysphagia occurred in 4 patients (13.3%). In this series, screw malposition was observed in two patients (6.6%). There were no esophageal, tracheal, or vascular injury complications.
DISCUSSION

The spinal surgeon is frequently encountered with conditions in the cervical spine in which corpectomy forms part of the solution. The surgeon has to deal with gap left after corpectomy. The cervical spine can be reconstructed using autograft, allograft or bone cement. Usually cervical corpectomy is performed to treat trauma-induced cervical cord compression, flexion-compression fracture with ventral canal compromise, and hyperextension injuries that cause central cord injury. Cervical corpectomy is performed in cervical spondylotic myelopathy (CSM) cases with predominantly anterior cord compression, and/or in
patients who have circumferential stenosis of the cervical spinal canal with cervical kyphosis. When a tumour involves the entire cervical vertebral body and PLL at the time of diagnosis, it is usually necessary to excise the entire vertebra and ligament.

Cervical corpectomy can be used to decompress the spinal cord in cases of spondylodiscitis and cases of epidural abscess anterior to the cord.

In this study 30 patients underwent cervical corpectomy; 18 cases (60%) for the treatment of trauma, 8 cases (26.7%) for degenerative spondylotic disease, three cases (10%) for infection and one case (3.3%) for ossification of posterior longitudinal ligament.

The use of an anterior cervical plate in the treatment of degenerative spine disease has several biomechanical advantages. The increased stability across the operative segment decreases motion between the graft and vertebral endplate and increases the chance of solid fusion. A reduced incidence of graft-related complications has also been observed with the use of anterior cervical plates.

The plate not only acts as a buttress preventing graft extrusion, but decreases the extent of graft collapse and subsidence, preventing the formation of postoperative cervical kyphosis. It can also maintain sagittal balance and preserve the normal biomechanics of the unfused cervical segments, contributing to a decreased incidence of postoperative axial neck pain and reduced potential for adjacent-level disease. In this study a cervical unicortical locking plate is placed in all cases.

The rate of neurological improvement for patients with CSM undergoing ventral surgical decompression has been reported to be 39 to 83%. Recently, Connolly, et al. reported an 83% rate of neurological improvement. They reported neurological improvement rates of 83%, 73%, and 66% following one-level, two-level, and three-level corpectomy, respectively, with grafting and plating. In the present study at the last follow-up; the results were excellent in 6 (20%) patients, good in 13 (43.3%) patients, fair in 6 (20%) patient and poor in five (16.7%) patients.

The rate of graft- and instrumentation-related complications, as well as the rate of nonunion, increases as the length of the fusion increases. The rate of nonunion has been reported to be 0 to 70% following multilevel corpectomy without plating, especially in patients undergoing fusion with allograft. Fernyhough, et al. reported a total autograft nonunion rate of 27% and a total allograft nonunion rate of 41% for ventral cervical fusion in cases with cervical spondylotic myelo-pathy. In their series, the rate of nonunion was 25% and 8% following two motion segment fusion, 22% and 43% following three motion segment fusion, and as high as 41% and 70% following four motion segment fusion using autograft and allograft, respectively. Using allograft, Zdeblick and Ducker reported 5% and 63% nonunion rates following one-level and two-level fusion, respectively.

The rate of fusion in this series occurred in 25 patients (83.3%). The rate of successful fusion is apparently increased by using instrumentation, especially with multiple corpectomies.

The use of instrumentation following ventral cervical surgery is, however, associated with instrumentation-related complications, such as screw back-out, screw malposition, and esophageal fistulas. In this series, screw malposition was observed in two patients (6.6%). There were no esophageal, tracheal, or vascular injury secondary to instrumentation-related complications.

Soft-tissue complications related to cervical corpectomy can be minimized by careful anterior exposure and adequate release of all tissue planes over the cervical spine. Secure positioning of self-retaining retractors will further minimize the risk of soft-tissue injury. When in place, the retractors should be intermittently released to limit the effect of long-term pressure on the adjacent anatomical structures. The rates of dysphagia and dysphonia following anterior cervical surgery are highly dependent on the magnitude and duration of symptoms required for the condition to be considered abnormal. Reported rates of dysphagia following anterior cervical disectomy and fusion range from 0% to 24%. The rate of transient hoarseness and dysphagia in the present study occurred in 4 patients (13.3%).

CONCLUSION

Advances in surgical techniques and spinal stabilization methods have expanded the role of corpectomy for the management of various degenerative, traumatic or infectious disorders of the cervical spine. In the properly selected individual, it allows for a direct decompression of the anterior epidural space and stabilization of the appropriate spinal motion segments.

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3. Connolly PJ, Esses SI, Kostuik JP: Anterior cervical fusion: outcome analysis of patients fused...
Urodynamic Study of Bladder Function in Patients with Lumbar Compression Disorders and the Effect of Decompressive Surgery

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Neurosurgery and Urology Departments, Banha University

ABSTRACT

Background: Patients with lumbar spinal canal compression not only experienced leg neuropathy but also lower urinary tract symptoms. There are few reports concerning the prevalence of bladder symptoms and the effect of decompression on urodynamic symptoms. Objectives: The goal of the present study is to determine the incidence of bladder symptoms and urodynamic findings in lumbar spinal compressive disorders and report on outcomes in patients who have undergone decompressive surgery.

Patients and Methods: This prospective study included 35 consecutive patients with lumbosacral root syndrome with or without overt bladder dysfunction. Patients were classified according to the preoperative urodynamic results into; Group I: patients with pre-operative normal bladder function, Group II: patients with pre-operative bladder dysfunction. Urodynamic study was conducted pre-operatively and 3 months after lumbar decompression.

Results: There was significant difference between the two studied groups regarding the occurrence of urological symptoms. In the present study, among those 18 patients in group II, areflexic bladder was the most frequent urodynamic diagnosis encountered in 12 (66.6%) patients and 6 (33.4%) of patients were with detrusor overactivity. 6 patients with areflexic bladder showed improvement post operatively. Patients with preoperative neuropathic detrusor overactivity became normal postoperatively.

Conclusion: Decompression surgery had a beneficial effect not only on urological symptoms but also on urodynamic study of bladder function.

Keywords: urodynamic study, lumbar stenosis, bladder function.

INTRODUCTION

Lumbar disc disease (LDD) and lumbar spinal stenosis (LSS), causing sciatic pain, can be complicated with urinary voiding dysfunction owing to the common location of somatic nerves and the parasympathetic nerves to the bladder in the cauda equina (15). The somatic nerves to the bladder, originating from the III and IV sacral segments, reach the external sphincter and other pelvic floor musculature. The parasympathetic pelvic nerves originate from the second to the fourth sacral segments of the spinal cord. They conduct the main excitatory input to the bladder. The sympathetic pathways are provided by the hypogastric nerves arising from I, II and III lumbar segments (2,12,25).

Lower urinary tract symptoms result from compression of the parasympathetic fibers of S2–S4 nerve roots innervating the bladder. However, the prevalence of lower urinary tract symptoms in patients with LSS or LDD varies, according to the literature, because of differences in subjective symptoms and urodynamic abnormalities (8,13,28). Previous reports have shown lower urinary tract symptoms with disc herniation in up to 50% of patients with matching urodynamic findings (8,9). According to the literature, the prevalence of lower urinary tract symptoms associated with LSS ranges from 50% to 80% (14).

The primary aims for treatment of neurogenic bladder are: Preservation of the upper tract function; ensuring that detrusor pressure remains within safe limits during both the filling phase and the voiding phase, Improvement of urinary continence to prevent urinary tract infection and Restoration of the lower urinary tract functions in patients with detrusor overactivity or detrusor sphincter dyssynergia (6,7,11,22).

The goal of the present study is to determine the incidence of bladder symptoms and urodynamic findings in lumbar spinal compressive disorders and report on outcomes in patients who have undergone decompressive surgery.

PATIENTS & METHODS

This prospective study included thirty five (35) consecutive patients with lumbosacral root syndrome due to lumbar disc prolapse and/or lumbar canal stenosis with or without overt bladder dysfunction, scheduled for surgery in the department of Neurosurgery at Banha University Hospital during the period from 2009 to 2012.

Inclusion Criteria:

- All patients (males and females) scheduled for surgery for lumbar intervertebral disc prolapse and/or lumbar canal stenosis.

Exclusion criteria:

- Active urinary tract infection.
- Patients with infravesical obstruction.
- Diabetic patients.
- Patients with vesicoureteral reflux.
- Patients with senile prostatic hyperplasia.
Patients grouping:
Patients were classified according to the preoperative urodynamic results into: **Group I:** patients with pre-operative normal bladder function. **Group II:** patients with pre-operative bladder dysfunction. Patients were subjected to the following workup:

**Thorough history taking,**

**Full clinical examination including:**

a) General examination
b) Clinical neurological examination
c) Urological examination

**Laboratory Investigations:**

**Radiological Investigation**

**Urodynamic evaluation**

Urodynamic study was conducted pre-operatively and 3 months after lumbar decompression by one urologist who was unaware of the final diagnosis and just conducted the study procedures objectively. At the beginning of the urodynamic study, an 8-F double lumen catheter was introduced into the bladder. After urination, the residual bladder volume was measured by aspirating residual urine through a catheter and measuring the volume using a syringe.

All urodynamic tests were done under the same circumstances, using the ANDROMEDA medizinische system. The tests were done under complete aseptic technique to all patients preoperatively and at least three months postoperatively.

**i) Uroflow:** Flow rates were recorded as patients voided privately in the sitting (women) or standing (men) position. Every patient was instructed to be relaxed, not to strain during micturition.

**ii) Cystometry:** With the patient supine a double lumen 8 Fr. urodynamic catheter (Forges - France) was introduced into the bladder transurethrally. One lumen was used for bladder filling with saline at room temperature at rate of 50 ml per minute. The other lumen was connected to an external pressure transducer for measuring the intravesical pressure. The catheter was taped with adhesive plaster to the medial side of the patient's thigh.

**iii) Pressure-flow studies of micturition:** When the patients have to urinate, bladder filling was stopped. The measuring system seatad to voiding phase. Readjustment of the height of pressure transducer was carried out. The patient was asked to cough to check pressure response. Then the patient was allowed to void.

In our study the diagnosis of detrusor areflexia was made according to the recommendation of the International Continence Society Committee on Standardisation of Terminology. Detrusor areflexia was diagnosed if the absence of detrusor contraction was indicated by simultaneous measurement of intravesical and abdominal pressure during the voiding phase. Due to the absence of detrusor contraction the patient voids by abdominal straining. In the presence of detrusor areflexia intravesical pressure increases through increased abdominal pressure. The diagnosis of "Detrusor Hypereflexia" was made if the presence of detrusor repeated contraction with muscle irritability and minor evoked ms potentials.

All patients were operated upon for decompressive lumbar surgery at the appropriate level by the surgical team in the neurosurgery department, Banha university hospital. All patients were conducted for follow up scheme same as preoperative work up at least 3 months postoperatively.

**RESULTS**

The present study included thirty five patients with lumbosacral root syndrome due to lumbar disc prolapse and/or lumbar canal stenosis with or without overt bladder dysfunction, scheduled for surgery in the department of Neurosurgery at Banha University Hospital. Patients' age ranged from 36 to 67 years (mean 48 years); 19 patients were male.

A diagnosis of LDD or LSS was confirmed in all patients, using radiological evidence. 15 cases (42.8%) had one-segment involvement, 11 cases (31.5%) had two-segment involvement, 6 cases (17.2%) had three-segment involvement and 3 cases had four segment involvements (8.5%). The Patients were classified preoperatively into two groups according to preoperative urodynamic function of the bladder:

**Group I:** patients with pre-operative normal bladder function (17 patients).

**Group II:** patients with pre-operative bladder dysfunction (18 patients).

There was significant difference between the two studied groups regarding the occurrence of urological symptoms. Fifteen of the patients (88.2%) from group I had no urological complaint and only two were symptomatic. On the other hand Urological symptoms were present in seventeen patients from group II (94.4%) in the form of stress incontinence, frequency, urgency, overflow dribbling, straining with incomplete evacuation and repeated urinary tract infection, while only one patient was urologically free.

**Post voiding residual urine (PVR) assessment:**

In group I, the residual of urine was below 45 ml., while in group II, residual urine volume ranged from 60-180.

Post operative (PVR) change was no significant in group I. Post operative (PVR) change was a significant parameter in the improvement of patients in group II (table 1).
Table (1): Pre and Post Operative PVR Volume In The Two Studied Groups

<table>
<thead>
<tr>
<th>Post Voiding Residual P V R (ML)</th>
<th>GROUP I NO=17</th>
<th>GROUP II NO=18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre op</td>
<td>Post op</td>
</tr>
<tr>
<td>NO</td>
<td>%</td>
<td>NO</td>
</tr>
<tr>
<td>0------30</td>
<td>13</td>
<td>76.4</td>
</tr>
<tr>
<td>31------60</td>
<td>4</td>
<td>23.6</td>
</tr>
<tr>
<td>61------120</td>
<td>0</td>
<td>00</td>
</tr>
<tr>
<td>91------120</td>
<td>0</td>
<td>00</td>
</tr>
<tr>
<td>121------180</td>
<td>O</td>
<td>OO</td>
</tr>
</tbody>
</table>

Preoperative and postoperative urodynamic studies:

**Maximum urinary flow rate (Q.max.):**

The maximum flow rate was measured for all patients (35 patients). The 17 patients of group I (48.5%) of patients had Q max >11mL/sec, two patients were with equivocal range and the others were normal rate. Post operative (Q.max.) change was insignificant parameter in the improvement of patients in group I.

The Q.max among 18 patients of group II ranged from 3 to 14 ml/sec with two patient only in the equivocal range while other sixteen were below accepted rate. Post operative (Q.max.) change among 18 patients of group II was significant parameter in the improvement of patients in group II as a post operative range was 6-20 ml/sec, with marked improvement of the pre op. values (table 2).

Table (2): Pre and Post Operative Q.Max in the Two Studied Groups

<table>
<thead>
<tr>
<th>Q.MAX (ml /SEC)</th>
<th>GROUP I NO=17</th>
<th>GROUP II NO=18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre op</td>
<td>Post op</td>
</tr>
<tr>
<td>NO</td>
<td>%</td>
<td>NO</td>
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<tr>
<td>0 - ----&lt; 10</td>
<td>0</td>
<td>00</td>
</tr>
<tr>
<td>11- ----&lt;15</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>16- ----&lt;20</td>
<td>15</td>
<td>88.2</td>
</tr>
<tr>
<td>21- ----&lt;25</td>
<td>0</td>
<td>00</td>
</tr>
</tbody>
</table>

Cystometry and pressure flow study:

In the present study, the first sensation to void preoperatively in group I patients ranged from (180 to 250) ml saline, postoperatively the first sensation ranged from (195 to 230) ml saline. It was insignificant improvement in bladder sensation. On the other hand in group II patients, the first sensation preoperatively ranged from (80 to 900) ml saline, postoperatively the first sensation was ranged from (150 to 700) ml saline. It was significantly improved in the first sensation.

In the present study, the cystometric capacity in group I patients preoperatively was ranged from 350 to 560ml saline and postoperatively it was ranged from 400 to 620 ml saline. It was insignificant as the cystometric capacity was within the normal limits pre- and postoperatively. The cystometric capacity in group II the range was 250 to 1600 ml saline preoperatively and ranged from 480 to 1150ml saline postoperatively, but here the difference was significant.

In the present study, among those 18 patients in group II areflexic bladder was the most frequent urodynamic diagnosis encountered in 12 (66.6%) patients and 6 (33.4%) of patients were with detrusor overactivity. The maximum detrusor pressure in 12 patients with areflexic bladder was ranged from 4 to 20 cm H2O while it ranged from 15 to 63 cm H2O in those 6 patients with neuropathic detrusor overactivity. The maximum detrusor pressure in the 17 patients in group I was ranged from 16 to 35 cm H2O.

In the present study, follow up of the 18 patients who had preoperative abnormal pressure-flow parameters (group II) for at least three months after surgical interference. We found that areflexic bladder was encountered in twelve patients preoperatively, six patients showed improvement post operatively Fig. (2). Patients with preoperative neuropathic detrusor overactivity became normal postoperatively Fig. (1).
Fig. (1): (a) Urodynamic study revealed decrease bladder capacity, with early detrusor overactivity and increase filling pressure. (Detrusor overactivity. (b) Post-op urodynamic study revealed: normal urodynamic study.

Fig. (2): (a) Urodynamic study revealed: low pressure, low flow, interrupted straining pressure with breathing and marked increase of bladder capacity (detrusor areflexia). (b) Post-op urodynamic study revealed: normal urodynamic study.
DISCUSSION

Bladder filling and emptying involve the peripheral sympathetic, parasympathetic and somatic innervations of the lower urinary tract (27). The sacral reflex centre (S2 – S4) participates in modulating bladder contraction and fullness. The conus medullaris in adults is usually located at the level of the first vertebral body (28). Thus, lumbar spinal stenosis usually causes lower rather than upper motor neuron lesions. Nerve compression may lead to structural neuronal damage, neuronal ischaemia or oedema, and axonal transport inhibition(17,24).

Previous reports have shown lower urinary tract symptoms with disc herniation in up to 50% of patients with matching urodynamic findings (9). According to the literature, the prevalence of lower urinary tract symptoms associated with LSS ranges from 50% to 80% (10). In this study, 54% of patients complained of urological symptoms.

Residual urine is defined as the volume of fluid remaining in the bladder immediately following the completion of micturition. The measurement of residual urine forms an integral part of the study of micturation. Under normal circumstances, the bladder should evacuate its content of fluid completely following normal voiding. Some patients with disc prolapse who develop bladder dysfunction have large capacity bladders that may also empty incompletely. This can coexist with initially high voiding pressure and an overactive detrusor (10).

In the present study, comparing the two groups of patients as regard the residual urine preoperatively, Only 4 patients (23.6%) in group I, baseline P.V.R. urine volume was high (>30 ml), but in other patients in the same group, the volume was (<30 ml). On the other hand P.V.R urine volume in group II patients was abnormally high in 11 patients ( >100 ml) and only 7 patients had residual volume (<100 ml). The difference in P.V.R.volume in both group was significant.

Follow up of patients at least three months postoperatively, for patients in group I the residual urine was normal (< 30 ml) in all patients. The difference between the residual volume pre and postoperative in group I was insignificant. For patients in group II there was also improvement in P.V.R. volume towards the normal side and the difference was significant. Deen et al. found that P.V.R urine volume is one of the most sensitive indicators of bladder function and its response to decompressive laminectomy(10).

Uroflowmetry is the only noninvasive urodynamic test available (24). It is a reflection of the final result of the act of voiding and is therefore influenced by a number of variables. These include the effectiveness of the detrusor contraction, the completeness of sphincter relaxation and the patency of the urethra (9). Because of these variables, Uroflowmetry cannot be used as a diagnostic study, but together with the measurement of residual urine it provides an estimate of the effectiveness of the act of voiding and is a rapid and economic screening tool (10).

In the present study, there was insignificant improvement in maximum urinary flow rate (Q max) in group I patients postoperatively. But, in group II patients there was significant improvement in Q max postoperatively. Maximum urinary flow rate and post voiding residual urine volume are indicators of detrusor function. Thus, improvement in these two factors may be considered as evidence of improved bladder function. Our results regarding the Q max improvement correlates with that found by Deen et al and Bartolin et al (4,10) in their work.

Cystometry remains the most accurate tool for evaluating the filling component of bladder function. During the course of cystometry information is sought regarding, the bladder's sensation, capacity, compliance and the occurrence of involuntary contraction (18). First sensation of bladder filling is the filling the patient has, during cystometry, when he/she first becomes aware of the bladder filling (26). Cockayne et al (9), reported that, vesical sensation could be, hypersensitive (volume at first sensation <150 ml) or hyposensitive (volume at first sensation > 250 ml) bladder.

In the present study, the first sensation to void preoperatively in group I patients ranged from (180 to 250) ml saline, while in the postoperative cystometry, the first sensation was ranged from (195 to 230) ml saline and it is insignificant improvement in bladder sensation. On the other hand in group II patients, the first sensation preoperatively ranged from (80 to 900) ml saline, postoperatively the first sensation was ranged from (150 to 700) ml saline and there is significant improvement in the first sensation.

In the present study, the cystometric capacity in group I patients preoperatively was ranged from 350 to 560ml saline and postoperatively it was ranged from 400 to 620 ml saline. It was insignificant as the cystometric capacity was within the normal limits pre- and postoperatively. In patients in group II the range was 250 to 1600 ml saline preoperatively and ranged...
from 480 to 1150 ml saline postoperatively, but here the difference is significant. 

Deen et al. (10) found that bladder capacity do not change significantly after operation. Bartolin et al. (1) reported that there is a significant improvement of bladder capacity postoperatively in both groups of patients with or without bladder dysfunction.

Preoperative pressure-flow studies were conducted for all patients and according to its results we classify the patients into 2 groups: Seventeen patients (48.5%) had normal pressure flow parameters and were diagnosed as normal as regard to the voiding function and named group I. Their maximum detrusor pressure was within the normal range, it was ranged from 13 to 30 cm H2O, while their maximum flow rate (Q max) ranged between 11 and 20 ml/sec. Bartolin et al. (4) reported more or less similar parameters for the patients with preoperative normal urodynamic studies.

Eighteen patients (51.5%) were diagnosed as abnormal as regard to the voiding function with abnormal pressure-flow parameters. Their maximum detrusor pressure ranged from 3 to 10 cm H2O, while their maximum flow rate (Q max) ranged from 6 to 12 ml/sec, for 12 patients with areflexic and underactive bladder, while the maximum detrusor pressure for the remaining 6 patients with neuropathic detrusor overactivity was ranged from 25 to 48 cm H2O. Bartolin et al. (4) found nearly the same, as maximum detrusor pressure in patients with detrusor dysfunction ranged from 6 to 24 cm H2O, while their maximum flow rate Q. max ranged from 2 to 16 ml/sec.

Detrusor areflexia correlates with obstructive voiding symptoms and stress incontinence due to overflow or lack of resistance at the level of the external sphincter. In the case of detrusor overactivity, patients usually complain of urgency and urge incontinence, and in some cases these symptoms are observed even when urodynamic testing is normal (1). In the present study, among those 18 patients in group II areflexic bladder was the most frequent urodynamic diagnosis encounters in (66.6%) of patients and (33.4%) of patients with detrusor overactivity.

Bartolin et al. (4) found detrusor areflexia was noted in 47.2% of the patients with lumbar intervertebral disc protrusion, detrusor overactivity was noted in cases with lumbar spinal stenosis. O’Flynn et al. (19) found 65% of patients had detrusor areflexia and, voided by straining. Sandri et al. (23) reported detrusor overactivity in 3 of 54 patients operated on for lumbar intervertebral disk protrusion but provided no data on preoperative urodynamic finding of those 3 patients. Bartolin et al. (4) concluded that bladder function usually remain unchanged after surgery for lumbar intervertebral disc protrusion, normal cystometric findings often remain normal postoperatively.

In the present study, follow up of the 18 patients who had preoperative abnormal pressure-flow parameters (group II) for at least three months after surgical interference. We found that areflexic bladder was encountered in twelve patients out of eighteen preoperatively, 6 patients postoperatively showed improvement of the cystometric findings. Patient group with preoperative neuropathic detrusor overactivity became normal postoperatively.

Bartolin et al. (4) reported that bladder function recovered in a small proportion of his patients with detrusor dysfunction namely areflexia (6 patients improved out of 27 after laminectomy).

The present study suggests that lumbar decompression contributes to relieving neurogenic bladder dysfunction in patients with lumbar compression disorders. Buchner and Schiltenwolf (5) reviewed 22 patients who underwent surgical decompression following a diagnosis of cauda equina syndrome due to LDH, 17 of whom (77%) recovered complete urinary function following surgery. Radulovic et al. (21) reported that 89% of patients with cauda equina syndrome, caused by disc herniation, achieved good or excellent results in bladder function recovery. No patient with normal urodynamic results in the present study developed abnormalities after surgery, which demonstrated that decompression surgery was an effective treatment with a good safety profile.

There were some inherent limitations to the present study, including the relatively small number of patients and the short follow-up period. Data from a larger patient population that include long-term outcomes are necessary to determine whether the results remain consistent.

CONCLUSION

Complete evaluation of the neural activity of patients with lumbar intervertebral disc prolapse and lumbar canal stenosis should include an examination of both somatic and visceral components. Preoperative normal bladder function in patients with LDD and LCS often remains normal after decompressive surgery. Decompression surgery had a beneficial effect not only
on urological symptoms but also on urodynamic study of bladder function.

REFERENCES

Original Article

Surgical Treatment of Idiopathic Syringomyelia on the Basis of Intramedullary Pulse Pressure Theory: A Report of Nine Cases with Clinical and Radiological Outcomes

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ABSTRACT

Background: The intramedullary pulse pressure theory would provide an explanation of the pathophysiology of idiopathic syringomyelia i.e. Syringomyelia develops where the systolic CSF passes through a regional narrowing in the subarachnoid space which leads to increase in CSF velocity and, according to the Bernoulli theorem, decrease in CSF pressure that would cause a suction effect (Venturi effect) on the spinal cord that distends the cord causing syrinx formation.

Objectives: The aim of this study is to describe the clinical and radiological outcomes of surgical management of idiopathic syringomyelia by decompressive laminectomy and syringosubarachnoid shunt on the basis of intramedullary pulse pressure theory.

Patients and Methods: This prospective case series study was conducted on nine patients with idiopathic syringomyelia who met our inclusion and exclusion criteria. All the patients were treated by decompressive laminectomy and syringosubarachnoid shunt. Clinical results were evaluated by using the criteria of Japanese Orthopaedic Association Scoring System for Cervical Myelopathy (JOA score). All the patients had preoperative magnetic resonance imaging (MRI) and postoperative MRI two weeks after surgery then every six months in the first year then every year. Radiological results were determined by measuring transverse diameter of the syrinx (TDS) / transverse diameter of the spinal cord (TDSC) percent from axial MRI at the maximum syrinx transverse diameter.

Results: The mean age of patients at time of surgery was 32 ±9.79 STD years. 55.6 % of patients were males and 44.4 % were females. The mean duration of symptoms was 54.7 ±25.00 STD months. All patients (100%) had spinothalamic sensory disturbance at time of surgery, 3 patients (33.3%) had posterior column disturbance, 2 patients (22.2%) had dissociative sensory loss, 5 patients (55.6%) had pain in upper limbs, 7 patients (77.8%) had flaccid weakness in upper limbs, 6 patients (66.7%) had spastic weakness in lower limbs and 2 patients (22.2%) had sphincteric disturbance. At the end of follow up (mean 42.4 ±12.12 STD months) the mean JOA score of the patients showed improvement from 8.2 ±2.53 STD before surgery to 14.4 ±1.42 STD and the mean recovery rate was 72.7 (±10.74 STD) %. Also the mean TDS / TDSC percent was reduced from 84 ±7.14 STD % before surgery to 21.1±3.58 STD %. Apart from transient posterior column manifestations, no complication related to surgery was present.

Conclusion: The intramedullary pulse pressure theory could explain the pathophysiology of idiopathic syringomyelia. Patients with idiopathic syringomyelia and progressive neurological deterioration could be treated by decompressive laminectomy, to increase the cross-sectional area of the subarachnoid space and stop further propagation of the syrinx, and syringosubarachnoid shunt, to relieve any residual increased pressure within the syrinx for better chance of neurological improvement.

Key Words: Bernoulli theorem, decompressive laminectomy, idiopathic syringomyelia, intramedullary pulse pressure, syringosubarachnoid shunt, venturi effect

INTRODUCTION

Syringomyelia is a cavity in the spinal cord containing fluid that is similar to cerebrospinal fluid (CSF) and extracellular fluid (ECF). The cavity may be formed by a dilatation of the central canal or lie within the parenchyma of the spinal cord. It may be lined by ependymal cells or gliotic tissue. The cavities are usually located inside the cervical cord, they can extend upwards (medulla oblongata and brain stem), and or downward (thoracic spinal cord), eventually may involve the whole spinal cord (holocord syringomyelia). It is a chronically progressive illness leading to increase neurological deterioration in the majority of cases. Its incidence is estimated to be 8.4 new cases / year / 100,000 people.

Syringomyelia can be caused by a variety of underlying pathological entities, Chiari I malformation, trauma, spinal cord tumor and adhesive arachnoiditis are the known causes of syringomyelia. There are many reports on the pathophysiology and treatment of these conditions. Syringomyelia not associated with any definite pathogenic lesions is known as idiopathic syringomyelia. The pathophysiology and management of such idiopathic syringes remain unclear because there are few reports on details of idiopathic syringomyelia.
Greitz (1995) described the concept of intramedullary pulse pressure which is based on the Bernoulli theorem. The Bernoulli theorem or the Venturi effect states that "the increase in fluid velocity in a narrowed flow channel decreases fluid pressure". Syringomyelia thus preferentially develops where the systolic CSF flow passes through a regional narrowing in the subarachnoid space which leads to increase in CSF velocity at or just caudal to this region and, according to the Bernoulli theorem, decrease in CSF pressure. The increased pulse pressure in the cord and the decreased pulse pressure in the surrounding CSF space would cause a suction effect (Venturi effect) on the spinal cord that distends the cord during each systole and syrinx develops by the accumulation of extracellular fluid in the distended cord.

The intramedullary pulse pressure theory could provide an explanation of the pathophysiology of syringomyelia whatever the etiology, e.g., Chiari I malformation, trauma, spinal cord tumor and adhesive arachnoiditis.

Delicate structures in the subarachnoid space such as intradural nerve roots, dentate ligament, trabeculae in the subarachnoid space, normal cord intumescences or bulging intervertebral disc can cause partial narrowing of the subarachnoid space. In idiopathic syringomyelia this partial narrowing in the subarachnoid space may hinder CSF flow leading to increased systolic CSF velocity and decreased CSF pressure at this region or immediately caudal to it causing Venturi effect with distention of the cord and formation of syringomyelia. Once syringomyelia is formed this will lead to more narrowing of the subarachnoid space with increased CSF velocity, decreased CSF pressure and Venturi effect that cause self progression of the syrinx.

Based on the above we assume that idiopathic syringomyelia with progressive neurological deterioration would be managed by decompressive laminectomy along the main bulk of the syrinx to increase the cross-sectional area of the subarachnoid space that would reduce the velocity of CSF flow and consequently increase CSF pressure in the subarachnoid space and reduce the Venturi effect to stop further propagation of the syrinx, and drainage of the syrinx to relieve any residual increased pressure within the cavity which may hinder neurological improvement.

In this case series study we describe the clinical and radiological outcomes of surgical management of idiopathic syringomyelia with progressive neurological deterioration by decompressive laminectomy and syringosubarachnoid shunt.

**PATIENTS AND METHODS**

This prospective case series study was conducted on nine patients with idiopathic syringomyelia who were treated by our technique of decompressive laminectomy and syringosubarachnoid shunting during the period between March 2005 and December 2010.

Inclusion criteria

Patients with idiopathic syringomyelia and suffering progressive neurological deterioration were included in this study (Figure 1). Also this study included cases associated with narrow posterior fossa and small cerebellar cisterns, a condition known as tight cistern magna (Figure 2), despite of some authors does not consider these cases as idiopathic syringomyelia.

![Figure 1: Sagittal T1-weighted MR images of a patient with idiopathic syringomyelia treated with posterior laminectomy and syringo-subarachnoid shunt, preoperative image (left) and postoperative image (right).](image-url)
Exclusion criteria
- Syringomyelia associated with Chiari malformation, spinal cord tumor, trauma, adhesive arachnoiditis, or other arachnoid pathology, which was confirmed by MRI, and MRI myelogram.
- Patients with stationary clinical course over the last year.
- Patients who lost postoperative follow up or had follow up less than two years.

Preoperative Evaluation
All patients were subjected to detailed history taking and full general and neurological examination. Clinical symptoms and signs were evaluated by direct questioning and examination using the criteria of the Japanese Orthopaedic Association Scoring System for Cervical Myelopathy (JOA score) as presented in Table 1.

Preoperative investigations included plain X-rays, Magnetic resonance imaging (MRI) with gadolinium enhancement and MRI myelogram of the entire spine in all patients to rule out other pathogenic lesions that can cause syringomyelia. In addition, all patients underwent cranial computerized tomography (CT) scanning to identify hydrocephalus. The length of the syrinx and the levels of extension were determined on the mid-sagittal MRI. The Size of the syrinx was measured from the axial MRI at the maximum syrinx transverse diameter, if the ratio of the transverse diameter of the syrinx (TDS) divided by that of the spinal cord (TDSC) at the same level exceeded 70%, the syrinx was considered as large (Figure 3).
Table 1: Japanese Orthopaedic Association Scoring System for Cervical Myelopathy (JOA score)\textsuperscript{17}

<table>
<thead>
<tr>
<th>Domain</th>
<th>Function</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper extremity: fingers (feeding, writing, fasten button)</td>
<td>Impossible: Unable to feed oneself, unable to write and unable to fasten buttons of any size</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Severe: Can manage to feed oneself’</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Moderate: Writing is possible but not practical, and/or large buttons can be fastened</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Mild: Writing is clumsy but practical, and/or cuff buttons can be fastened</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Normal: Normal feeding, writing and fasten buttons</td>
<td>4</td>
</tr>
<tr>
<td>Sensor</td>
<td>Upper extremity: shoulder and elbow function (evaluated by MMT score of the deltoid or biceps muscles, whichever is weaker)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Severe: MMT 2 or less</td>
<td>–2</td>
</tr>
<tr>
<td></td>
<td>Moderate: MMT 3</td>
<td>–1</td>
</tr>
<tr>
<td></td>
<td>Mild: MMT 4</td>
<td>–0.5</td>
</tr>
<tr>
<td></td>
<td>Normal: MMT 5</td>
<td>0</td>
</tr>
<tr>
<td>Lower extremity: gait</td>
<td>Unable to stand up and walk by any means</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Able to stand up but unable to walk</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Severe: Unable to walk with a cane or other support on a level</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Able to walk without support but with a clumsy gait</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Moderate: Walks independently on a level but needs support on stairs</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Able to walk independently when going upstairs, but needs support when going downstairs</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Mild: Capable of fast but clumsy walking</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Normal: Normal gait</td>
<td>4</td>
</tr>
<tr>
<td>Sensory</td>
<td>Upper extremity: Complete loss of touch and pain sensation</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Severe: 50% or less normal sensation and/or severe pain or numbness</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Moderate: More than 60% normal sensation and/or moderate pain or numbness</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mild: Subjective numbness of slight degree without any objective sensory deficit</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Normal: Normal sensation</td>
<td>2</td>
</tr>
<tr>
<td>Trunk</td>
<td>Complete loss of touch and pain sensation</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Severe: 50% or less normal sensation and/or severe pain or numbness</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Moderate: More than 60% normal sensation and/or moderate pain or numbness</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mild: Subjective numbness of slight degree without any objective sensory deficit</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Normal: Normal sensation</td>
<td>2</td>
</tr>
<tr>
<td>Bladder</td>
<td>Urinary dysfunction: Complete loss of touch and pain sensation</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Severe: Urinary retention and/or incontinence</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Moderate: Sense of retention and/or dribbling and/or thin stream and/or incomplete continence</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mild: Urinary retardation and/or pollakiuria</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Normal: Normal urinary function</td>
<td>3</td>
</tr>
</tbody>
</table>

Total for normal patient = 17  
MMT = manual muscle test
Surgical technique

After medication and general anesthesia, all patients were positioned prone on frame to avoid abdominal compression and reduce venous congestion. The head was fixed in three-pins skull fixator with slight flexion of the neck. Posterior midline skin incision was made in the neck followed by bilateral paraspinal muscle separation from the spinous processes and the laminae. Under fluoroscopic guidance, bilateral laminectomy was done at the level of the main bulk of the syrinx with preservation of the facet joint. In cases associated with narrow posterior fossa and small cerebellar cisterns in addition to posterior laminectomy, cranio cervical decompression was also performed (suboccipital craniectomy plus C1 laminectomy) (Figure 2). After that the ligamentum flavum was excised with a rongeur. With the use of operating microscope a small posterior midline dural incision (about 3 cm length) was made at the level of the lower part of the syrinx. The dura was subsequently fixed to the paravertebral muscles with 4-0 silk sutures. While making the dural incision, care was taken to avoid injury to the arachnoid membrane. Utilizing microsurgical technique, a small incision was made in the posterior midline of the arachnoid membrane. The incision was extended with microsissor. Care was taken to preserve the arachnoid membrane to ensure proper placement of the distal end of the shunt in an intact subarachnoid space and to avoid later arachnoid adhesions. Utilizing a microknife, a small, longitudinal midline incision (about 3mm length) was made in the posterior median sulcus (an avascular area) of the spinal cord between the posterior columns at the lower pole of the syrinx. The borders of the incision were dissected until the syrinx was reached. Thereafter the proximal tapered end of a valveless silastic tube (about 5 cm length and 1.4 mm outer diameter) with side holes was inserted into the syrinx cavity in a cephalad direction for about 2 cm while the other end was inserted into the subarachnoid space (Figure 4). After that the arachnoid was returned to its normal position. Rounded tip needle with 4-0 silk thread was passed through one edge of the dura, around the tube, then through the other edge of the dura. A tie was made including both dural edges and the tube. Tighten was done to the extent that fix the tube but did not occlude it (Figure 5). Closure of the dura matter was done with continuous 4-0 vicryl sutures. Closure of the muscle, subcutaneous tissue and skin were then done in a routine fashion. All patients received prophylactic antibiotics perioperatively and were encouraged to ambulate the day after surgery. The use of hard neck collar for three weeks was suggested for all the patients.

Figure 4: One end of the tube is inserted into the syrinx cavity through a posterior midline myelotomy while the other end is inserted into the subarachnoid space.

Figure 5: The tube is fixed to both dural edges with 4-0 silk thread.

Postoperative Evaluation

The patients were followed up at regular intervals for at least two years. Clinical symptoms and signs were evaluated postoperatively by using the criteria of the JOA score as presented in Table 1. Clinical results after surgery were assessed according to the recovery rate as described by Hirabayashi et al. Postoperative magnetic resonance imaging (MRI) was done two weeks after surgery then every six months in the first year then every year. Radiological outcome after surgery was determined by comparing the preoperative and postoperative maximum transverse diameter of syrinx / transverse diameter of spinal cord at the same level (TDS / TDSC) percents (Figure 3).
Statistical Analysis

Statistical analysis was performed using SPSS 16.0 for Windows statistic software. Variables were described as frequencies and mean ± standard deviation. Paired-sample T test was used to compare the differences of pre- and postoperative results. Also nonparametric 2 related samples, Wilcoxon test was used when indicated. Bivariate correlation between variables was made by using Pearson’s correlation coefficient. A p value of less than 0.05 was considered significant.

RESULTS

Preoperative data

The study was conducted on nine patients who met our inclusion and exclusion criteria during the period between March 2005 and December 2010. Two of these patients (22.2 %) had narrow posterior fossa and small cerebellar cisterns. The mean age of patients at time of surgery was 32 ±9.79 STD (range 19 - 46) years. Five patients were males (55.6 %) and four were females (44.4 %). The mean duration of symptoms was 54.7 ±25.00 STD (range 24 -96) months. All patients (100%) had spinothalamic sensory disturbance at time of surgery, 3 patients (33.3%) had posterior column disturbance, 2 patients (22.2%) had dissociative sensory loss, 5 patients (55.6%) had pain in upper limbs, 7 patients (77.8%) had flaccid weakness in upper limbs, 6 patients (66.7%) had spastic weakness in lower limbs and 2 patients (22.2%) had sphincteric disturbance (neurogenic bladder). Patients’ symptoms and signs at time of surgery were summarized in Table 2. The mean preoperative JOA score was 8.2 ±2.53 STD (range 5 - 13). The syrinx was extended along the length of 5 vertebral levels in four patients (44.4%) and 7 vertebral levels in two patients (22.2%), 4 vertebral levels in one patient (11.1 %), 6 vertebral levels in one patient (11.1%) and 8 vertebral levels in one patient (11.1%). All patients had large syrinx, the maximum transverse diameter of syrinx/transverse diameter of spinal cord at the same level (TDS /TDSC) percent ranged from 73%-92.5% (mean 84±7.14 STD%). The preoperative demographic, clinical and radiological findings for each case were summarized in Table 3.

Analysis of the preoperative data showed highly significant negative correlation between the preoperative JOA score and the size of the syrinx (TDS /TDSC percent). However there was no other significant correlation between the preoperative JOA score and the other preoperative variables (Table 4, Graph 1).

Table 2: Symptoms and signs at time of surgery

<table>
<thead>
<tr>
<th>Symptoms and signs</th>
<th>Number of patients</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in upper limbs</td>
<td>5</td>
<td>(55.6%)</td>
</tr>
<tr>
<td>Spinothalamic sensory disturbance</td>
<td>9</td>
<td>(100%)</td>
</tr>
<tr>
<td>Posterior column disturbance</td>
<td>3</td>
<td>(33.3%)</td>
</tr>
<tr>
<td>Dissociative sensory loss</td>
<td>2</td>
<td>(22.2%)</td>
</tr>
<tr>
<td>Flaccid weakness in upper limbs</td>
<td>7</td>
<td>(77.8%)</td>
</tr>
<tr>
<td>Spastic weakness in lower limbs</td>
<td>6</td>
<td>(66.7%)</td>
</tr>
<tr>
<td>Sphincteric disturbance</td>
<td>2</td>
<td>(22.2%)</td>
</tr>
</tbody>
</table>
**Table 3: Preoperative data**

<table>
<thead>
<tr>
<th>Case NO.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Duration of symptoms (months)</th>
<th>Preoperative JOA score</th>
<th>Levels</th>
<th>Preoperative TDS / TDSC percent</th>
<th>Narrow posterior fossa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>Male</td>
<td>30</td>
<td>7</td>
<td>C3 – T2 = 7</td>
<td>89.4</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>Male</td>
<td>72</td>
<td>6.5</td>
<td>C2 – C6 = 5</td>
<td>91.1</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>Female</td>
<td>48</td>
<td>13</td>
<td>C4 – T1 = 5</td>
<td>73.0</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>Male</td>
<td>60</td>
<td>5</td>
<td>C2 – T1 = 7</td>
<td>92.5</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>39</td>
<td>Female</td>
<td>96</td>
<td>9</td>
<td>C4 – T2 = 6</td>
<td>80.2</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
<td>Female</td>
<td>42</td>
<td>8.5</td>
<td>C3 – C7 = 5</td>
<td>83.7</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>Male</td>
<td>24</td>
<td>11</td>
<td>C1 – T1 = 8</td>
<td>75.4</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>32</td>
<td>Female</td>
<td>36</td>
<td>8</td>
<td>C3 – C7 = 5</td>
<td>80.6</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>46</td>
<td>Male</td>
<td>84</td>
<td>6</td>
<td>C3 – C6 = 4</td>
<td>89.9</td>
<td>-</td>
</tr>
</tbody>
</table>

*(maximum Transverse Diameter of Syrinx divided by Transverse Diameter of Spinal Cord at the same level) × 100

**Graph 1: Interpolation line shows highly significant negative correlation between the preoperative JOA score and the preoperative TDS / TDSC percent.**

**Postoperative outcome**

The mean duration of follow up after surgery was 42.4±12.12 STD (range 24 – 60) months. All patients suffered from variables degrees of posterior column manifestations, which were attributed to the myelotomy incision, in the immediate postoperative period that improved gradually within few weeks and months. However, this was associated with progressive improvement in both motor and spinothalamic manifestations. At the end of follow up all the patients got benefit from surgery. The mean JOA score of the patients showed improvement from 8.2±2.53 STD (range 5-13) before surgery to 14.4 ±1.42 STD (range 12.5–16.5) at the final follow up. This improvement in the JOA score was statistically significant by using paired-sample T test (p value = 0.004). The mean recovery rate was 72.7 (±10.74 STD) % (range 57.1 % - 87.5 %). MR imaging demonstrated reduction in the size of the syrinx in the early postoperative follow up and this reduction continued with the progress of follow up, however residual syringomyelia was still present at the final follow up. The mean TDS / TDSC percent was reduced from 84 ±7.14 STD (range 73% - 92.5) % before surgery to 21.1±3.58 STD (range 16.8–27)% at the final follow up. This reduction in the size of the syrinx was statistically significant by using nonparametric 2 related samples, Wilcoxon test (p value= 0.008). The postoperative clinical and radiological outcomes for each case were summarized in Table 5.

Analysis of the postoperative results showed no significant correlation between the postoperative JOA score and postoperative size of the syrinx (TDS/TDSC percent) or the follow up period after two years (Table 6). However there was positive significant correlation between the postoperative JOA score and the preoperative JOA score. Also there was negative significant correlation between the postoperative JOA and the preoperative size of the syrinx (TDS/TDSC percent) (Table 7, Graph 2).

Apart from the transient posterior column manifestations which were attributed to myelotomy incision, no complication related to surgery was present. None of the patients have developed deformity of the spinal column, nor have shown relapse of the syringomyelia or the symptoms during the follow up period.
Table 5: Postoperative clinical and radiological outcomes

<table>
<thead>
<tr>
<th>Case NO.</th>
<th>Postoperative JOA score</th>
<th>Recovery rate</th>
<th>Postoperative TDS / TDSC percent</th>
<th>Follow up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>80.0 %</td>
<td>20.2 %</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>57.1 %</td>
<td>23.0 %</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>16.5</td>
<td>87.5 %</td>
<td>17.5 %</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>66.7 %</td>
<td>16.8 %</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>87.5 %</td>
<td>23.3 %</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
<td>64.7 %</td>
<td>18.6 %</td>
<td>36</td>
</tr>
<tr>
<td>7</td>
<td>15.5</td>
<td>75.0 %</td>
<td>27.0 %</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>14.5</td>
<td>72.2 %</td>
<td>25.0 %</td>
<td>32</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>63.6 %</td>
<td>18.7 %</td>
<td>24</td>
</tr>
<tr>
<td>Mean</td>
<td>14.4 ±1.42 STD</td>
<td>72.7 (±10.74 STD) %</td>
<td>21.1±3.58 STD %</td>
<td>42.4 ±12.12 STD</td>
</tr>
</tbody>
</table>

Table 6: Correlations between postoperative JOA score and postoperative size of syrinx and follow up

<table>
<thead>
<tr>
<th>Postoperative JOA score</th>
<th>Postoperative TDS / TDSC percent</th>
<th>Follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson correlation</td>
<td>.222</td>
<td>-.136</td>
</tr>
<tr>
<td>Significant (2-tailed)</td>
<td>.566</td>
<td>.727</td>
</tr>
</tbody>
</table>

Table 7: Correlations between postoperative JOA score and preoperative variables

<table>
<thead>
<tr>
<th>Postoperative JOA score</th>
<th>Age</th>
<th>Sex</th>
<th>Duration of symptoms</th>
<th>Preoperative JOA score</th>
<th>Levels</th>
<th>Preoperative TDS / TDSC percent</th>
<th>Small posterior fossa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson correlation</td>
<td>-.256</td>
<td>.537</td>
<td>-.262</td>
<td>.846*</td>
<td>.296</td>
<td>-.852*</td>
<td>.077</td>
</tr>
<tr>
<td>Significant (2-tailed)</td>
<td>.507</td>
<td>.136</td>
<td>.496</td>
<td>.004</td>
<td>.439</td>
<td>.004</td>
<td>.843</td>
</tr>
</tbody>
</table>
*correlation is significant, p value = .004

Graph 2: Correlations between the postoperative JOA score and the preoperative JOA score (left), and the preoperative TDS / TDSC percent (right).

**DISCUSSION**

There are few studies that discussed the pathophysiology of idiopathic syringomyelia. Most reports in the field of syringomyelia come from work done on Chiari I malformation. Three sources of origin for syringomyelia fluid were described: CSF entrance from the fourth ventricle, CSF entrance from the subarachnoid space, and extracellular fluid origin.

The theory of Gardner and Angel regarding CSF entrance from the fourth ventricle was supported by success of their procedure that involved closure of the obex along with cranio cervical decompression. The validity of this theory is now questioned by cine-mode MR imaging studies that did not demonstrate any CSF entrance from the fourth ventricle into the syrinx. The procedure performed by Gardner and Angel has also been reported to have the same results without closure of the obex. In their review of pathological specimens,
Milhorat et al. reported that syringes that communicated with the fourth ventricle were mostly found in children with hydrocephalus.

Also there are many question marks about the theory that increased subarachnoid pressure propelling CSF into the syrinx via the perivascular spaces since such a pressure might actually compress the cavity. Moreover, many studies have not consistently identified a pressure gradient that would favor CSF flow into the syrinx from the subarachnoid space. Ellertsson and Greitz reported that intramedullary spinal pressure exceeded the subarachnoid pressure in the patients who underwent percutaneous syrinx puncture. Many studies demonstrated that syringosubarachnoid shunting is effective in collapsing syringes and this does not go with the theory assuming CSF entrance from the subarachnoid space.

Many studies supported an extracellular origin of syringomyelia fluid. The exact mechanism, however, is still debated. Greitz (1995) described the concept of intramedullary pulse pressure. The intramedullary pulse pressure theory suggests that the distending force in the production of syringomyelia is a relative increase in pulse pressure in the spinal cord compared to that in the surrounding subarachnoid space. The formation of a syrinx then occurs by the accumulation of extracellular fluid in the distended cord from the relatively high pressure in the microcirculation of the spinal cord. Greitz depended on the Bernoulli theorem while describing his concept. The Bernoulli theorem or the Venturi effect states that "the total mechanical energy of flowing fluids remains constant, so the increased fluid velocity at a narrowed flow channel decreases the pressure in the fluid". Syringomyelia thus preferentially develops where the systolic CSF flow passes through a narrow region in the subarachnoid space which leads to an increase in CSF velocity at or just caudal to this region and, as a consequence of the Bernoulli theorem, decrease in CSF pressure. The increased pulse pressure in the cord and the decreased pulse pressure in the surrounding CSF space would cause a suction effect (Venturi effect) on the spinal cord that distends the cord during each systole and syrinx develops by the accumulation of extracellular fluid in the distended cord.

Other publications from other investigators support the intramedullary pulse pressure theory. The intramedullary pulse pressure theory is the first concept able to provide an explanation of the pathophysiology of syringomyelia whatever the etiology, e.g., Chiari malformation, spinal trauma, spinal cord tumor or adhesive arachnoiditis.

Delicate structures in the subarachnoid space such as intradural nerve roots, dentate ligament or trabeculae in the subarachnoid space and bulging intervertebral disc can cause partial subarachnoid narrowing especially at the mid and low cervical region where the cross-sectional area of the subarachnoid space is normally decreased by the cervical intumescence. In idiopathic syringomyelia this narrowing in the subarachnoid space may hinder CSF flow leading to increased systolic CSF velocity and decreased CSF pressure causing Venturi effect that distends the cord at or immediately caudal to this narrowing. This would explain why the most common site of idiopathic syringomyelia is located in the cervical region. Once syringomyelia is formed this will lead to more narrowing of the subarachnoid space with increased CSF velocity, decreased CSF pressure and Venturi effect that cause self progression of the syrinx.

This was the rationale of our technique for treatment of idiopathic syringomyelia with progressive neurological deterioration, which consisted of decompressive cervical laminectomy along the main bulk of the syrinx and drainage of the syrinx with syringosubarachnoid shunt. The first step of surgery, decompressive laminectomy, was aiming to increase the cross-sectional area of the subarachnoid space which reduces the velocity of CSF flow and consequently increases CSF pressure in the subarachnoid space which reduces the Venturi effect to stop further propagation of the syrinx. The second step of surgery, syringosubarachnoid shunt, was aiming to relieve any residual increased pressure within the syrinx by means of direct drainage of the fluid outside the spinal cord to offer better chance for neurological improvement.

Significant craniocervical blockage is common in patients presenting with narrow posterior fossa and foramen magnum, i.e. the so-called Chiari 0 malformation. In this fixed type of craniocervical obstruction, the pressure from cranially directed CSF pulse waves caused by a cough or straining may also be reflected into the most cranial part of the cervical cord. So in cases associated with narrow posterior fossa or tight cisterna magna we added craniocervical decompression to restore CSF flow dynamics.

Many procedures have been described for drainage of the syrinx including percutaneous needle aspiration of the syrinx, syringostomy, syringosubarachnoid shunting and extrathecal shunting via syringoperitoneal or syringopleural shunt.

There is reported benefit from percutaneous needle aspiration of syrinx cavities, however it cannot be repeated regularly. To provide continuous drainage local syringostomy has been performed by many surgeons, however this allows continuous drainage of the syrinx for sometime. Numerous materials and methods have been used including gutta percha drain, rubber drains, polyethylene tubing, cotton wicks, silk sutures and tantalum wire sutures. These materials are mainly used to maintain the patency of the outlet rather than as a conduit for drainage and some are
not recommended because possible reactions to them may cause arachnoiditis and malfunction.\textsuperscript{31}

Extrathecal shunting has been used by many authors with favorable results.\textsuperscript{1,2,14,34} Reported complications of extrathecal shunting procedures include CSF leak from the dural exit of the catheter, intestinal obstruction or perforation in syringoperitoneal shunting and pulmonary contusion, pneumothorax or pleural effusion in syringopleural shunting.\textsuperscript{1,2,14,34} Also peritoneal and pleural adhesions are causes of extrathecal shunt malfunction.\textsuperscript{33} Overshunting can occur due to siphonage of CSF from the syrinx or spinal subarachnoid space, along the inside or outside of the shunt tube to the pleural cavity or the peritoneal cavity where the pressure is lower than in the CSF pathway.\textsuperscript{34} This overshunting may be a cause of low pressure headache\textsuperscript{3} or marked deterioration of the patient’s condition due to hindbrain impaction which causes distortion and traction upon the lower cranial nerves as well as impacting the long tracts and cranial nerve nuclei in the foramen magnum.\textsuperscript{34} The use of antisiphon devices to overcome this complication would produce shunt malfunction.

Because previously reported operative results have not been good\textsuperscript{14,21-28} the syringosubarachnoid shunt has not been popular.\textsuperscript{14} With progress in microsurgical technique and improvement in the materials used for shunts, the syringosubarachnoid shunt is again receiving attention.\textsuperscript{14,16,27,31,32} Tator et al.\textsuperscript{31} reported good results with syringosubarachnoid shunt for treatment of syringomyelia, demonstrated an improvement in 11 out of 20 patients (55%). Isu et al.\textsuperscript{14} in their operative results with syringosubarachnoid shunt for treatment of syringomyelia, symptomatic improvement was demonstrated in 24 out of 28 patients (82%). Some authors\textsuperscript{34} denied the effectiveness of syringosubarachnoid shunting and discussed that a syringosubarachnoid shunt simply provides a free communication between the inside and outside of the syrinx and exposes the cyst to acute filling of fluid during Valsalva maneuvers. Padovani et al.\textsuperscript{37} reported that there was no evidence of this phenomenon in the 29 cases in their series treated with syringosubarachnoid shunting. They assumed that, sudden rises of pressure within the subarachnoid space in response to coughing, sneezing, and other maneuvers are more likely to spread over the wide outside aspect of the spinal cord than impel fluid within the syrinx through a small myelotomy. The disappearance of the syringes or their progressive collapse at postoperative MRI studies in all their patients, even those who did not improve after surgery, favored this hypothesis. In their study, morbidity related with syringosubarachnoid shunting was zero.

In our series, all the patient got benefit from surgery with a mean recovery rate 72.7 (±10.74 STD) % at the end of follow up. Also all the patients had reduction of their syrinx, the mean TDS / TDSC percent was reduced from 84 ±7.14 STD % before surgery to 21.1±3.58 STD % at the final follow up (Table 5). Apart from the transient posterior column manifestations which were attributed to myelotomy incision, no complication related to surgery was present.

As mentioned before the high incidence of favorable results with syringosubarachnoid shunts was due largely to the use of microsurgical techniques and silastic shunt materials.\textsuperscript{14,31} In our technique we used a piece of silastic tube like that which is used in lumbar CSF drainage catheter. This valveless tube would allow complete collapse of the syringomyelic cavity and decrease the risk of shunt malfunction. Other advantages of this tube include its negligible thickness, good anatomical adaptability to the posterior aspect of the cord, not easily kinked, can be fixed tightly to the dural edges without fear of obstruction and little tendency of its material to produce arachnoid reactions. In our series, we did not need to reoperate because of shunt malfunction (relapse of the syringomyelia or the symptoms) during mean follow-up period of 42.4 ±12.12 STD (range 24 – 60) months.

Although none of the patients in our study developed postoperative kyphotic deformity due to the laminectomy procedure, we recommend latera mass plate fixation if there is any preoperative vertebral subluxation or kyphosis and if the facet joints have been disrupted during the laminectomy procedure.

In contrast to Magge et al.\textsuperscript{24} in our study the preoperative clinical picture had highly significant negative correlation with the preoperative size of the syrinx, however there was no other significant correlation between the other preoperative variables (Table 4, Graph 1).

In contrast to some reported series\textsuperscript{1,12,13,31} and like other some reported series,\textsuperscript{27,32} we did not find any significant correlation between the postoperative clinical outcome and the preoperative duration of symptoms. However, we had significant correlation between the postoperative clinical outcome and both the preoperative clinical picture and the preoperative size of the syrinx. Interestingly and like other studies,\textsuperscript{9} we did not find significant correlation between the postoperative clinical outcome and the postoperative size of the syrinx or the follow up period after two years. (Table 7, Graph 2).

Simple comparison of our results with results in literature was difficult because of the differences in surgical indication, surgical technique and the criteria for the evaluation of results.

The management strategies outlined above should only be reserved for clearly symptomatic patients with progressive neurological deterioration as patients may had stationary course for many years in some cases. Many authors reported conservative treatment of asymptomatic idiopathic syringomyelia or idiopathic
syringomyelia with mild symptoms through serial imaging.26

What is critical in this study is the limited number of cases. However this was due to the paucity of cases with idiopathic syringomyelia and our restriction to cases with progressive neurological deterioration only and postoperative follow up period not less than two years.

CONCLUSION

The intramedullary pulse pressure theory could explain the pathophysiology of idiopathic syringomyelia. Patients with idiopathic syringomyelia and progressive neurological deterioration could be treated by decompressive laminectomy, to increase the cross-sectional area of the subarachnoid space and stop further propagation of the syrinx, and syringosubarachnoid shunt, to relieve any residual increased pressure within the syrinx for better chance of neurological improvement. This procedure has favorable outcome, is free from mortality and carries a very low morbidity.

REFERENCES


Original Article

Post-operative Lumbar Pseudomeningocele: Management and Evaluation

Mohammed El-Wardany, M.D.
Department of Neurosurgery, Ain Shams University

ABSTRACT

Background: lumbar pseudomeningocele is considered as an uncommon complication of spinal surgery. Studies concerned with this complex formation are still few. Objectives: the aim of the present study was to evaluate the clinical results of treating post-operative lumbar pseudo-meningocele. Risk factors for the formation of pseudomeningocele were also discussed. Patients and Methods: this is a retrospective study done on 12 patients who developed symptomatic lumbar pseudo-meningocele after various spinal surgeries between 2000 and 2011. All patients were operated upon in Ain Shams University Hospitals (Cairo, Egypt). All patients who developed post-operative pseudomeningocele were studied clinically and radiologically (Magnetic Resonance Imaging MRI, Computed Tomography CT, X-ray of lumbosacral region) to assess the pseudo-meningocele and the neurological status before and after any procedure. All patients had a cerebrospinal fluid diversion by lumbar drainage. Three cases had satisfactory results, one patient needed a percutaneous evacuation, and eight cases needed surgical repair. Results: 12 patients (7 males and 5 females) with post-operative lumbar pseudomeningocele, were included in this study. Eight patients had surgical repair. Follow up ranged from (6 to 24) months with a mean follow up of (17.4) months. The clinical state of the patients preoperatively was: back pain (58.3%), headache (25%), nausea/vomiting (16.6%) and limb pain/numbness (33.3%). Clinical outcome as described by Wang revealed excellent in 10 patients and good in 2 patients. Conclusion: iatrogenic pseudomeningocele is a rare complication of spinal surgery and should be suspected in patients submitted to lumbar surgery when delayed post operative neurological symptoms occur. Key word: pseudomeningocele, laminectomy, dural tear, cerebrospinal fluid CSF leak.

INTRODUCTION

Pseudomeningocele is a rare complication of spinal surgeries. It is an extradural accumulation of cerebrospinal fluid (CSF) in the soft tissue of the back that extravasates through the dural tear. The causes of pseudomeningocele may be classified into three categories: iatrogenic, traumatic, and congenital. By far the most common cause is iatrogenic, which results from unintended dural tears during spinal surgery. Pseudomeningocele often occurs as a complication of lumbar spinal surgery. Because different mechanisms have been used to explain the pathophysiology of pseudomeningocele, a precise definition is lacking.

Most investigators consider a pseudomeningocele as an extavasated collection of extradural CSF that result from a dural tear. Because the extradural fluid may be contained in an arachnoid-lined membrane or in a fibrous capsule, multiple terms to describe this entity exist. Pseudomeningocele has at various times, been referred to as meningocele spurious, false cyst, or pseudocyst. Some authors advocate the use of the term “meningocele” because many are found to have arachnoid-like cell lining. Most authors however, prefer the term “pseudomeningocele” because, at least initially, the lesion may not be arachnoid lined. Accordingly, it’s not a true meningocele. Simply because if the proper milieu exists, the extradural fluid collection may be reabsorbed and the communication between the intra-dural and extra-dural space may cease to exist.

The exact incidence of post-operative lumbar pseudomeningocele is unknown because many of these patients are asymptomatic. Another more likely reason is that spine surgeons are reluctant to publish negative result.

PATIENTS & METHODS

Patient’s population and study design: this is a retrospective study done at the Neurosurgery Department of Ain-Shams University Hospitals from 2000-2011.

This study concerned with lumbar pseudomeningocele after spinal surgery. 12 patients (7) males and (5) females were included in this study. The age ranged from 24 years to 53 years with a mean age of 35.6 years. The mean duration of symptoms prior to surgery was 13 months with a range from 5 months to 25 months.

In this study, the 12 cases of post operative pseudomeningocele occurred after various spinal surgeries for different lesions. Six cases had recurrent...
herniated lumbar intervertebral disc (4 at “L4-5” level and 2 at L5-S1 level). 5 cases had herniated lumbar intervertebral disc (4 at “L4-5” level and one at “L5-S1” level). Whereas only one patient had grade II spondylolysis at L4-5 level.

All patients had full general and neurological examination. MRI was done to all cases before any procedure to confirm a fluid collection connecting with the dural sac Figure (1). This was repeated 3 months later to confirm the resolution and recurrence of pseudomeningocele. CT of lumbo-sacral spine was also done to all cases to assess the site, extent, and size of the fluid collection. Plain X-ray of lumbosacral spine (antero-posterior and lateral) was done to check the alignment of the spinal vertebra. Guidelines for inclusion criteria in this study were those patients who had developed a dural tear recognized in 9 cases or not in 3 cases during surgery. Detailed reviews of charts for all of the patients were conducted to determine the method of treatment.

The patients were asked about headache, low back-pain and leg pain. A rating of "excellent" indicated complete resolution of the preoperative symptoms with no back pain; a rating of "good" indicated nearly complete resolution of the preoperative symptoms with minor back pain; and a rating of "poor" indicated symptoms that were worse than preoperative.

In this study, C.S.F diversion by lumbar drainage had a satisfactory result in treating only 3 cases with post-operative pseudomeningocele. The lumbar drain was removed after 5-7 days. Only one asymptomatic case, with a subcutaneous lumbar collection had a percutaneous puncture done and 60 ml of cerebrospinal fluid were aspirated. After that the patient was immobilized for 5 days in Trendelenburg position with a compressive abdominal corset. Follow up MRI after two months showed marked reduction in the size of the collection which disappeared in the second control MRI 3 months thereafter. The rest of the patients (8) needed further surgical interference.

Surgical technique and approach:

After medication and general anesthesia, all patients were positioned prone on a Wilson frame or rolls to avoid abdominal compression and hence reduce venous congestion. The skin was opened through the old operation scar. The pseudomeningocele sac was exposed subcutaneously. Dissection around this subcutaneous portion of the sac was done, until the defect in the lumbar fascia was encountered. The subcutaneous portion of the pseudomeningocele sac communicated via this defect with the deeper part located beneath the lumbar fascia extending to the dura forming a para-spinal CSF collection. The cavity of the sac was opened and clear CSF was evacuated. Further laminectomy was needed in 4 cases. Cauda equina filaments were found in the cavity in a 2 cases. The inferior wall of the para-spinal portion of the sac was found glistening. In 8 cases, a hole was identified in the bottom of the pseudomeningocele cyst (measuring about 2-3mm diameter). This hole presented the site of previous dural tear Figure (2). The extradural cyst wall was gently dissected from the dura and totally excised. The dural tear was repaired with interrupted 4.0 sutures. Interrupted figure -of- eight sutures of the myofascial layer were used to provide a watertight closure.

Figure (1): T2W2 sagittal MRI of lumbo-sacral spine showing post-operative pseudomeningocele
All patients were followed up clinically and radiologically. MRI lumbosacral spine (LSS) was done within two months after surgery to detect any residual cyst collection. Control MRIs were then done after (3, 6, 12 months) intervals to follow the resolution of the pseudomeningocele.

RESULTS

Patient’s demographics as shown in table (1): 12 patients were included in this retrospective study. Seven patients (58.3%) were males and five patients (41.6%) were females. Age ranged from 24 to 53 years with a mean of 35.6 years.
Table (1): Demographic data of the patients and type of intervention.

<table>
<thead>
<tr>
<th>Patient Number</th>
<th>Age/sex Mean=356 years ± SD (9.4)</th>
<th>Indication of initial operation</th>
<th>Level of lesion</th>
<th>Initial operation</th>
<th>Dural tear</th>
<th>Type of intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33/male</td>
<td>Recurrent herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>2</td>
<td>36/female</td>
<td>Recurrent herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>3</td>
<td>41/female</td>
<td>herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy and fenestration</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>4</td>
<td>45/male</td>
<td>Recurrent herniated intervertebral disc</td>
<td>L5-S1</td>
<td>microdiscectomy</td>
<td>unnoticed</td>
<td>Lumbar drainage</td>
</tr>
<tr>
<td>5</td>
<td>50/male</td>
<td>Recurrent herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>6</td>
<td>53/male</td>
<td>herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy and fenestration</td>
<td>noticed</td>
<td>Lumbar drainage</td>
</tr>
<tr>
<td>7</td>
<td>24/male</td>
<td>herniated intervertebral disc</td>
<td>L5-S1</td>
<td>microdiscectomy and fenestration</td>
<td>unnoticed</td>
<td>Percutaneous evacuation</td>
</tr>
<tr>
<td>8</td>
<td>27/female</td>
<td>Spinal canal stenosis</td>
<td>L4-5</td>
<td>Laminectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>9</td>
<td>29/male</td>
<td>Spinal canal stenosis</td>
<td>L4-5</td>
<td>Laminectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>10</td>
<td>31/male</td>
<td>Recurrent herniated intervertebral disc</td>
<td>L4-5</td>
<td>microdiscectomy and fenestration</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>11</td>
<td>29/female</td>
<td>Spinal canal stenosis</td>
<td>L4-5</td>
<td>Laminectomy</td>
<td>noticed</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>12</td>
<td>30/female</td>
<td>Spondylyolysis grade II</td>
<td>L4-5</td>
<td>Laminectomy with posterior instrumentation</td>
<td>unnoticed</td>
<td>Lumbar drainage</td>
</tr>
</tbody>
</table>

SD = Standard Deviation

Presenting symptoms included back-pain, headache, nausea, vomiting, or limb pain and numbness. In table (2) the main symptoms and signs are reported.

Table (2): Presenting clinical state in 12 patients:

<table>
<thead>
<tr>
<th>Clinical state</th>
<th>No. of cases</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulging mass</td>
<td>12</td>
<td>100%</td>
</tr>
<tr>
<td>Symptoms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)-back pain</td>
<td>7</td>
<td>58.3%</td>
</tr>
<tr>
<td>(ii)- headache</td>
<td>3</td>
<td>25%</td>
</tr>
<tr>
<td>(iii)- nausea / vomiting</td>
<td>2</td>
<td>16.6%</td>
</tr>
<tr>
<td>(iv)-limb pain / numbness</td>
<td>4</td>
<td>33.3%</td>
</tr>
<tr>
<td>(v)-asymptomatic</td>
<td>1</td>
<td>8.3%</td>
</tr>
</tbody>
</table>
### Table (3): Perioperative data of the patients and their clinical outcome

<table>
<thead>
<tr>
<th>Patient number</th>
<th>Duration of symptoms (Mean= 13± SD (5.9) months)</th>
<th>Size of pseudomeningoecele (Length x Width x Depth) cms</th>
<th>Dural repair with: Sutures Patch deep fascia</th>
<th>Clinical outcome according to Wang 35</th>
<th>Complication</th>
<th>Follow up (months) (Mean=17. 4± SD (5.1))</th>
<th>Recurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>4 x 3 x 1</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6 x 4 x 2</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>S.W.I</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>5 x 4 x 2</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>4 x 2 x 2</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>21</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>3 x 2 x 1</td>
<td>+</td>
<td>-</td>
<td>good</td>
<td>T.P.F.D</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>6 x 4 x 2</td>
<td>-</td>
<td>+</td>
<td>excellent</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>6 x 5 x 3</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>5 x 2 x 1</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>7 x 6 x 4</td>
<td>-</td>
<td>-</td>
<td>excellent</td>
<td>22</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>5 x 3 x 1</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>24</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>3 x 2 x 1</td>
<td>+</td>
<td>-</td>
<td>excellent</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>8 x 7 x 5</td>
<td>-</td>
<td>+</td>
<td>good</td>
<td>21</td>
<td>-</td>
</tr>
</tbody>
</table>

+= Present; -= Absent
S.W.I = Superficial Wound Infection
T.P.F.D = Temporary Partial Foot Drop

All patients were under follow up for at least 6 months (range 6-24 months; mean 17.4 months). No operative mortality was recorded in these 12 patients. Mild temporary neurological deterioration (partial foot drop) was seen in the early post operative period in one patient who had an entrapped nerve root within the pseudomeningoecele. Within a few weeks, this patient improved and became neurologically free. Superficial wound infection was noticed in one patient, that responded well to antibiotics (anti staphylococcus for 10 days). Perioperative data and clinical outcome are shown in table (3). In nine cases there was a dural tear in the initial surgery, and in three they were unnoticed. Attempts for dural repair with sutures in the initial operation were done. Three tears were successfully repaired with sutures. Muscle graft was used in 6 tears which were not easily accessible because of their far-anterolateral location.

The mean size of pseudomeningoecele was 5.1 cm in length, 3.6 cm in width and 2.1 cm in depth as measured by MRI. In only two cases, a patch of deep fascia graft was used to repair complex laterally located dural tears. No CSF leaks or wound collection was found in the post-operative period. No recurrence was recorded except in one case which developed recollection after 3 months post-operatively. Aspiration of CSF collection was done with the insertion of a lumbar drainage for one week -undercover of broad spectrum antibiotics- and the collection disappeared. All patients were reassessed with full neurological examination and MRI (LSS) within the first postoperative 3 months, and every 6 months thereafter for the first two years.

**DISCUSSION**

A dural tear is one of the most common complications encountered in spine surgeries. Its incidence ranges from 1% to 17%.22,2,4,7,35,16,18,9,10 A general belief is that spine surgeons tend to underestimate the frequency of this complication.17. Reported risk factors for incurring a durotomy include older age, revision surgery, anatomic variation, thinning of dura and inexperience of the surgeon.13,30,3. This study includes 12 patients with clinically and radiologically post operative lumbar pseudomeningoecele, this include 7 (58.3 %) males and 5 (41.6 %) females. Mean age is 35.6 years with range (24-53 years). All patients showed pseudomeningoecele with clinical presentation with a mean duration of symptoms of 13 months.

Weng Y et al.36 reported in their retrospective study which was between October 2000 and March 2008, that there were 11 patients who developed symptomatic pseudomeningoeceles after spinal surgery. This included 7 (63.6%) males and 4 (36.3%) females whose ages ranged from 19 to 68 years (means 40.8 years). The mean duration of symptoms prior to intervention was 2.5 months, with a range of 1 to 4 months.

Tosun B et al.34 stated in their retrospective study which was between 2006 and 2010 that there were 5 patients who developed symptomatic...
Post-operative Lumbar Pseudomeningecele

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Pseudomeningecele after spinal surgery. This included (60%) males and (40%) females whose ages ranged from 19 to 67 years (mean 40.2 years).

As regard the presenting symptoms and signs in this study, there were back pain (58.3%), headache (25%), nausea or vomiting (16.6 %), limb pain (33.3%) and asymptomatic (8.3%). Follow up was done for all patients for at least 6 months (range 6-24 months) with mean of 17.4 months. Weng Y et al.36 reported in their series that the commonest symptoms were back pain (63%), headache (55%), nausea or vomiting (36%) and pain or numbness in the limbs (18%). Follow up was done of all patients for at least 8 months with a mean of 16.5 months.

Tosun B et al.34 reported in their study that the commonest symptoms were back pain, headache, nausea and vomiting. Numness in the legs or radiculopathy were not encountered.

As regard the clinical outcome and complication, in this study, 9 (74.9%) patients had an excellent outcome and 2 (16.6%) patients had a good outcome as described by Wang35. In this study superficial wound infection was noticed in one patient and completely resolved with antibiotics. Temporary partial foot drop was the second complication which was recorded in another patient. Recurrence of pseudomeningecele after surgical repair was only seen in one patient. Aspiration of CSF collection was done with the insertion of a lumbar drainage and the collection disappeared.

Tosun B. et al.34 stated in their series that complication such as neurological deficits or superficial or deep wound infections did not develop. Recurrences of pseudomeningecele after the treatment were not seen in any patients. Nine patients had an excellent outcome, 2 a good outcome and one a poor outcome.

Weng Y et al.36 reported in their study that complications such as neurological deficits, wound infection, or deep infection was not observed. A recurrence of pseudomeningecele during the follow up period was not observed for their study population.

In this study, dural tear in the initial surgery was noticed in nine cases, out of twelve. Three dural tears were successfully repaired with sutures. Those six cases with a durotomy located in a difficult site (far/anterolateral) muscle graft was used.

Weng Y. et al.36 stated in their study that dural tears during the initial surgery were noticed in all patients who subsequently sustained postoperative pseudomeningecele. The entire dural tear had been primarily repaired at that time.

Tosun B. et al.34 reported in their series that dural tears during the initial surgery were not recognized during the surgical operation. Post operative pseudomeningecele resulted from a tear in the dura mater and pia-arachnoid that is un-noticed and is left open during surgery32,38,26,25. If the dura mater and pia-arachnoid are torn, CSF extravasates into the paraspinal soft tissue space. More cases of pseudomeningecele developed in the lumbar region than other areas. This observation is in accordance with this study and with other studies37,19,22,14. This may be because CSF in the lumbar region is under a higher hydrostatic pressure than that in the cervical spine in the upright posture, and because more surgical procedure is carried out on the lumbar spine 12.

A pseudomeningecele should be considered in patients with recurrent back pain, radicular pain, or a persistent headache after spinal surgery which is matching with our study11,28.

Nerve roots may subsequently herniated via the dural and arachnoid tears leading to radicular pain and may be motor deficits. Headache may be the result of a reduction in CSF volume and lowered intracranial pressure11,25,8.

Most authors consider MRI to be the most effective non-invasive diagnostic tool that can accurately assess the size and the site of pseudomeningecele. In this study MRI was done to all patients before any procedure and was repeated 3 months later to confirm the formation, resolution and recurrence of pseudomeningecele.

According to the literature, recommendations, for the treatment of dural tears have included primary repair, closed subarachnoid drainage, grafts consisting of muscle, fat or fascia, blood patches, and bed rest16,18,9,6,5,21,20,15.

A dural tear that is observed during the spinal surgery should certainly be repaired primarily due to the well known risks of CSF leakage. There is a general consensus that, if possible, the surgeon should perform a primary suture closure33. Adequate exposure of the tear is necessary for the proper repair of the dural tear. Paraspinous muscles and fascia should always be re-approximated tightly. Otherwise extradural anatomic dead space that is created by surgical procedures leading to the leakage of CSF may not be obliterated. The relatively significant sub-periosteal dissection with resultant lateral muscle retraction can result in a larger dead space into which CSF can leak after closure. With minimally invasive procedure, the resulting dead space is significantly small34.

Unnoticed or unrepaired dural tears may stay asymptomatic, but sometimes lead to a pseudomeningecele formation. The prevalence of this complication remains unknown35. There are few reports of clinical outcomes after incidental durotomy in the literature. Sin et al.30 reported that the overall outcome of the patients would not be affected adversely by the presence of a dural tear. On the contrary, Saxler et al.27 reported poorer clinical outcome after surgery in patients with an incidental durotomy.
In this study, dural tears which were not noticed intra-operatively in 3 patients were due to their small size. This small size of the dural defects might be reason for success without surgical intervention in those 3 patients. So, prompt identification and careful closure of the dural defect at the time of the index surgery should be the treatment of choice. Dural tears were identified in 8 patients at the time of initial surgery that lead to subsequent symptomatic pseudomeningocele formation and reoperation. This implied that the initial leaks of CSF were not completely closed even though the entire dural tear had been repaired by primary closure at that time. This again emphasizes the importance of having a more careful attention in dealing with intra-operative CSF leaks.

Comparisons among different treatment modalities (either conservative or surgical) for pseudomeningocele may be considered as one of some limitations of the present study due to the small number of the patients. Such limitations may be discussed in the future studies.

CONCLUSION

Iatrogenic pseudomeningocele is a rare complication of spinal surgery and should be suspected in patients submitted to lumbar surgery when delayed post operative neurological symptoms occur, even many months or years after the initial surgery. There is no distinct treatment guideline according to the etiology in the current literature. Any dural opening made during lumbar surgery should be tightly and carefully closed at the time of the original procedure.

REFERENCES


Multilevel Lumbar Spondylolisthesis: Comparative Study between two Surgical Fusion Techniques

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Department of Neurosurgery, School of Medicine, Cairo University

ABSTRACT

Background: Degenerative lumbar spinal stenosis is a common pathology characterized by multilevel disc herniation and lumbar spondylolisthesis, which are difficult to treat. Objectives: The current study aimed to compare the short-term clinical outcomes of two surgical techniques of management of this pathology. Patients & Methods: 40 patients of multilevel lumbar spondylolisthesis were included in this study. Patients were randomly divided into two groups according to the surgical approach used in treatment. Group (A): Were operated upon by posterior decompression, transpedicular screw fixation and posterolateral intertransverse bony fusion. Group (B): was operated upon by posterior decompression, transpedicular screw and transforminal lumbar interbody fusion (TLIF). Results: Statistical significance was reached in terms of surgery time, blood loss, hospital stay, and fusion rates, but there was no significant difference between the two groups as regards the post-operative JOA score and the complication rates. Conclusion: The application of the lumbar interbody cage (TLIF cage) proved to have better fusion rates than intertransverse bony fusion, but still intertransverse bony fusion gives same results regarding postoperative clinical improvement with shorter hospital stay and operative time.

Keywords: multilevel lumbar spondylolisthesis, fusion rates, JOA score, TLIF, posterolateral fusion.

INTRODUCTION

Spondylolisthesis is defined as the forward displacement of one vertebra relative to another. This “slip” usually occurs when the locking mechanism constituted by the laminae and facet joints has failed, 90% of cases occur at the L4/L5 and L5/S1 levels. Six types of listhesis have been described according to the Wiltse-Newman-MacNab classification system and include the isthmic, degenerative, dysplastic, traumatic, pathologic and iatrogenic forms. Spondylolisthesis can be graded by Meyerding grading system according to the degree of anterior translation of the top vertebral body in relationship to the bottom vertebral body into four grades. Nonoperative management is the primary treatment for patients with low-grade adult degenerative spondylolisthesis who present with acute or chronic low back pain. However, studies have shown that up to one third of patients with isthmic or degenerative spondylolisthesis are at risk for progressive lithesis which may lead to neurological deficiencies.

Indications for operative treatment include failure of conservative therapy for at least two months, disturbing postural abnormality, neurological deficit, observed slip progression. Operative treatment employs variable combinations of decompression, bony fusion, and instrumentation. This can be achieved by a variety of methods including anterior interbody, posterior interbody, posterior, intertransverse, or transforminal lumbar interbody fusion. However, intertransverse fusion has gained the widest clinical acceptance. The fusion rates in lumbar spine surgery can vary according to the technique. Although numerous studies on spinal fusion have been conducted, their outcomes are so inconsistent that it is difficult to determine which approach provides the highest fusion rate. Therefore, in this study, an attempt was made to compare fusion rates between two of the most prevalent surgical fusion techniques. The addition of multiple levels in the surgery increases the complexity of the procedure somewhat and also increases the risks compared to single-level fusion surgery. Potential problems with blood loss, arterial and venous thrombosis, and post-operative wound infections are directly related to the length of surgery, and multilevel procedures generally take longer than single-level fusions.

PATIENTS & METHODS

This study included 40 patients of multilevel lumbar spondylolisthesis. All cases tried conservative measures for at least two months of active physiotherapy program, non-steroidal anti-inflammatory medications & lumbar brace before going to surgical treatment. The patients were randomly chosen and divided into two groups according to the surgical approach used in treatment.

- Group (A): patients will be operated upon by posterior decompression, transpedicular screw fixation and posterolateral intertransverse bony fusion.
**Group (B):** patients will be operated upon by posterior decompression, transpedicular screw and transforminal lumbar interbody fusion (TLIF).

All cases were operated upon in Kasr El-Aini Hospitals, Cairo University between November 2011 and August 2012. The follow-up period ranged from 6 to 11 months.

Full personal history was taken from all cases. Full preoperative and postoperative neurological examination was also done for all cases. The Japanese Orthopedic Association (JOA) evaluation system for measuring low-back pain syndrome was utilized.

Operative technique: General anesthesia was administered in all cases; patients were positioned in the prone position. The C-arm was used to confirm the location of the pathology and to plan the pedicle screw insertion. A midline skin incision was used overlying the affected level with exposure of one or two levels above and below that level for adequate exposure; the dissection was carried down to the fascial level. The paraspinal musculature was dissected off the spinous processes, laminae and facets using electro cauterezation or subperiosteal muscle separation. Adequate bony and ligamentous decompression was then performed in all cases followed by transpedicular screw fixation of the affected levels.

In group (A) patients dissection was continued laterally over the transverse processes using electro cauterezation. The bony surface of the transverse processes was decorticated with a pituitary rongeur or a drill. The bone removed from the decompression was packed over the decorticated transverse process after the soft tissue had been removed adequately.

In group (B) patients Exposure of the disc space was done on one side by removing the facet joints and protecting the nerve roots. The disc space was entered and disc material was removed. An interbody cage, filled with bone graft was placed into the disc space to maintain the disc height.

Clinical follow-up: Assessment was done with JOA score and physical examination immediately postoperative, and then at 3 months intervals postoperatively.

**Statistical Methods:** All of the statistical analyses were processed on a personal computer running commercially available software (SPSS, Inc. & Microsoft Office Excel 2010). Depending on the characteristics of the variables being compared, various tests were used. A probability value of less than or equal to 0.05 was considered to indicate statistical significance. Mean data were presented.

**RESULTS**

The data collected from 40 cases of surgically managed spondylolisthesis was analyzed. Patients were randomly divided in the two groups. The mean age in group (A) was 45.3 years, while in group (B) it was 52 years, which shows no statistical significance. In group (A); 8 cases were males (40%) and 12 cases were females (60%), while in group (B) 9 males (45%) and 11 females, this has no statistical significance (By Chi-square x²). The mean BMI (body mass index) was 31.7 in group (A) and 32.5 in group (B), this also had no statistical significance. (By student t test) Clinical presentation: Most of the cases presented with back pain and claudicating pain in both groups. In group (A) patients had higher percentage of cases presenting with sciatica 46.6% than group B 22.6 %( fig.1).

Radiologically The number of fusion levels in group (A) was 3 levels in 14 cases 4 levels in 6 cases, while in group B was 3 levels in 16 cases and 4 levels in 4 cases, and this has no statistical significance (By Chi-square x²).

![Figure (1): presenting clinical picture in both groups.](image-url)
Table (1): Preoperative (JOA score)

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Significance *</th>
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<tbody>
<tr>
<td>Preoperative (JOA score)</td>
<td>6.8</td>
<td>6.6</td>
<td>N.S</td>
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<tr>
<td>Low-back pain</td>
<td>1.2</td>
<td>1.1</td>
<td>N.S</td>
</tr>
<tr>
<td>Leg pain</td>
<td>1.5</td>
<td>1.3</td>
<td>N.S</td>
</tr>
<tr>
<td>Walking ability</td>
<td>1.4</td>
<td>1.5</td>
<td>N.S</td>
</tr>
<tr>
<td>Straight leg raising test</td>
<td>0.7</td>
<td>0.6</td>
<td>N.S</td>
</tr>
<tr>
<td>Sensory abnormality</td>
<td>0.9</td>
<td>1.1</td>
<td>N.S</td>
</tr>
<tr>
<td>Manual muscle testing</td>
<td>1.1</td>
<td>1</td>
<td>N.S</td>
</tr>
</tbody>
</table>

* By Student t test

Table (2): Post-operative clinical evaluation.

<table>
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<th>Group B</th>
<th>Significance *</th>
</tr>
</thead>
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<td>Postoperative (JOA score)</td>
<td>14.1</td>
<td>14.3</td>
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<td>Low-back pain</td>
<td>2.8</td>
<td>2.9</td>
<td>0.13</td>
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<td>Leg pain</td>
<td>2.9</td>
<td>2.8</td>
<td>0.07</td>
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<tr>
<td>Walking ability</td>
<td>2.6</td>
<td>2.9</td>
<td>0.042</td>
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<tr>
<td>Straight leg raising test</td>
<td>2</td>
<td>2</td>
<td>0.23</td>
</tr>
<tr>
<td>Sensory abnormality</td>
<td>1.9</td>
<td>1.8</td>
<td>0.35</td>
</tr>
<tr>
<td>Manual muscle testing</td>
<td>1.9</td>
<td>1.9</td>
<td>0.47</td>
</tr>
<tr>
<td>Rate of improvement %</td>
<td>89.1</td>
<td>92.1</td>
<td>0.137</td>
</tr>
</tbody>
</table>

*By Student t test

**Post-operative Clinical Evaluation:**
- No statistical difference between the two groups as regard the post-operative JOA score except that group (A) had significant lower post-operative walking ability score (shorter claudicating distance) than does the fusion group (B) (P<0.05).
- Group (B) had higher mean rate of improvement 92.1% than does group (A) 89.1% with no statistical difference (P>0.05).

**Complications and hospital stay:**
- The mean hospital was 2.7 days in Group (A) and 4.2 days in Group (B), which was statistically significant (P less than 0.05). 2 cases had infection in group (A) and 1 case in group (B). 1 case has CSF leak in group (B), this wasn’t statistically significant.
- The mean operative time was 3 hours (2-4 hours) in group (A), significantly shorter than group (B) which was 5 hours (3-6 hours). The mean blood loss was significantly lower in group (A) 400cc, than group (B) 700cc. Figure (2)

Figure (2): mean duration of operation and blood loss in both groups.

**Postoperative fusion:** There was a clear statistical significance between fusion rates in both groups. 85% of cases (17 patients) showed signs of fusion in Group B versus 65% in group A (13 patients). P= 0.029.
Figure (3): A and B: Preoperative X-ray and MRI of a female patient with history of trauma 1 year ago, showing fracture pars L4-5, L5S1 and spondylolisthesis. C and D: Postoperative X-ray showing decompression and posterolateral fusion.

Figure (4) showing images of a 55 yrs. male patient with past history of previous laminectomy L3,4,5 and discectomy L3-4, L4-5 one year ago. Left: MRI showing L3,4,5 spondylolthesis. Right: postoperative image after L3, 4,5 fixation with posterolateral screws and TLIF cages.
DISCUSSION

Multilevel lumbar spondylolisthesis is a common problem. Treatment choices are either conservative care or operative intervention. Non operative methods are effective in the treatment of most patients with symptomatic lumbar spondylolisthesis and spinal stenosis. Surgery was advised to patients in this study who failed to respond to a reasonable trial of non-operative treatment for 8 weeks.

The mean age in our study was 49 years, which is noticeably younger than many studies. Jacobsen et al., reported a mean age of 68 years in men and 71 years in women. Booth et al., reported mean age of 66 years in their study.

Both groups were operated upon by adequate decompression of the nervous structures through removal of compressing bony, ligamentous and disc elements. This was reflected in results regarding postoperative clinical improvement, no statistical significance was found between the degree of improvement, by comparing pre and post-operative JOA score, 89.1 in group A versus 92.1% in groups B. (p=0.137).

We found no significant difference in complications rate between the two studied groups. This is coinciding with Ghogawala et al., who reported similar rate of superficial infection and no difference in complication rate between two groups. This could be explained by the limited number of cases that lead to an overall low complication rate. Hospital stay is non-significantly higher in TLIF fusion group than PL fusion group; too many authors also reported this finding.

The main statistical difference in our study was noticed in aspects of operative time, blood loss, and postoperative fusion rates. The average blood loss in posterolateral fusion was 400ml compared to 700ml blood losses in interbody fusions, this results was coinciding with results reported by McAfee et al. and Coe and Vaccaro. In our study the average time for multilevel posterolateral fusion was 3 hours, versus 5 hours in TLIF group, which is significant, which also coincided with the results reported by Coe and Vaccaro.

As regard fusion we have a fusion rate of 85% in the TLIF group in a mean follow up period of 11 months, this is coinciding with Tokuhashi et al., who had a fusion rate of 92.8% over 3 years follow up. The posterolateral group showed 65% fusion rate after 9 months follow up. La Rosa et al evaluated 35 consecutive patients who underwent pedicle screw fixation for isthmic spondylolisthesis, with 18 cases having PL fusion and 17 having PLIF. At 2-year follow-up, the correction of subluxation, disc height, and foraminal area were maintained in the PLIF group but not in the PL fusion group, these differences were statistically significant.

CONCLUSION

The application of the lumbar interbody cage (TLIF cage) proved to have better fusion rates than inter transverse bony fusion, but still intertransverse bony fusion gives same results regarding postoperative clinical improvement with shorter hospital stay, intraoperative blood loss, and operative time.
REFERENCES


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