Bone Sandwich Closure Technique for Posterior Fossa Craniectomy

Shyam Sundar Krishnan¹ Pulak Nigam¹ Adarsh Manuel¹ Madabushi Chakravarthy Vasudevan¹

¹Achantha Lakshmipathi Neurosurgical Centre, Voluntary Health Services, Chennai, Tamil Nadu, India

Address for correspondence Shyam Sundar Krishnan, MS, MCh, Achantha Lakshmipathi Neurosurgical Centre, Voluntary Health Services, TTTI Post, Taramani, Chennai 600113, Tamil Nadu, India (e-mail: shyamsundarkrishnan76@gmail.com).

J Neurol Surg B 2020;81:8–14.

Abstract

Background Surgery of posterior fossa including cerebellopontine (CP) angle involves either craniectomy or craniotomy. While there has been precedence of craniotomy in recent practice, the preferred access in resource-strapped centers still remains been craniectomy. Although the latter offers an excellent exposure, it is believed to carry increased risk of postoperative pseudomeningocele and cerebrospinal fluid (CSF) leak compared with craniotomy.

Keywords

- posterior fossa
- bone sandwich
- CSF leak
- pseudomeningocele
- craniectomy

Methods We have suggested a technique by which after standard craniectomy for the posterior fossa surgeries the bony defect is covered by Gelfoam bone sandwich (GBS) technique. We studied this technique over a period of 25.6 years in 1,028 patients.

Results and Conclusion We analyze the risk of pseudomeningocele and CSF leak in our patients using GBS technique and reviewed literature to compare our outcomes with standard craniotomy and craniectomy procedures.

Introduction

Pseudomeningocele and cerebrospinal fluid (CSF) leak remain the most common complication encountered in posterior fossa surgeries, whether cerebellopontine (CP) angle, unilateral, or midline suboccipital approaches.^{1,2} Among all the factors which these complications have most commonly been associated with, one is the kind of bony exposure that has been opted for craniotomy or craniectomy. Given the small surgical area, traditionally, craniectomy was preferred for the easy and wide exposure with less risk of sinus and dural tear besides other factors.¹ However, craniectomy has been associated with increased risk of pseudomeningocele and CSF leak.^{1,3–8} Cranioplasty or craniotomy with bone flap replacement would then seemingly be the preferred option to prevent the above complications and is evidenced by precedence of the same in recent practice; yet craniectomy is still practiced in resource-strapped centers. We share our experience of a novel and simple alternative to standard postcraniectomy bony defect closure techniques.

Aim

The main purpose of this article is to provide an alternative and novel technique for posterior fossa craniectomy defect closure with bone and Gelfoam sandwich to avoid CSF leak/pseudomeningocele.

Materials and Methods

The study was conducted on patients who presented with posterior fossa pathology and were operated on. These patients may on occasion have hydrocephalous at time of presentation. We do not routinely place shunts for patients having preoperative hydrocephalus unless patient has clinically significant hydrocephalus and is symptomatic.

Inclusion Criteria

All patients who underwent a posterior fossa surgery, including CP angle and other posterior fossa tumors, surgery for auditory brain stem implant and decompressive craniectomy,

received

August 18, 2018

accepted after revision

January 7, 2019

published online

February 4, 2019

© 2020 Georg Thieme Verlag KG
Stuttgart · New York

DOI <https://doi.org/10.1055/s-0039-1678602>.
ISSN 2193-6331.

between January 1991 and June 2016 in our department, were included in our study. Patients were followed up through regular outpatient department visits, once weekly for first month and once a month thereafter for 6 months. This was managed by regular telephonic and/or postal communication. Those with a minimum follow-up period of 6 months were included in the study.

Exclusion Criteria

Patients who underwent craniotomy were excluded from the study since presence of postsurgical scars makes the dural closure difficult and was considered to be a potential confounding factor. Those with a follow-up period of less than 6 months were also excluded.

Surgical Technique

In all our patients, we routinely place a burr hole ("safety burr hole") at Frazier's point to enable tapping of ventricles should the need be in the perioperative and postoperative period.

Following this, standard posterior fossa craniectomy (retromastoid or mid-line suboccipital) was performed by placing three to four burr holes with standard perforators, and drills equipped with protective guard and remaining bone was removed with rongeurs. The bone bits and bone dust were saved and were placed in saline till the end of the procedure. At the end of the procedure, type of dural closure was recorded (watertight dural closure or watertight duraplasty or overlay graft [overlay duraplasty] with autologous fascia, fat). Valsalva maneuver was used to check and classify the dural closure as watertight or not.

Gelfoam Bone Sandwich Technique

The technique of preparation and placement of bone sandwich is outlined as below and depicted sequentially in ►Fig. 1:

1. Craniectomy is performed in standard technique using perforators, drills, and rongeurs (►Fig. 1a).
2. The bone dust and bits generated during this procedure are collected in saline.
3. A piece of Gelfoam approximately the size of craniectomy defect is cut sideways like a submariner sandwich (►Fig. 1b).
4. The collected bone dust and bits are squeeze dried and placed in between the leaves of Gelfoam (►Fig. 1c and d).
5. The bone sandwich is now placed over the dura in the craniectomy defect (►Fig. 1e and 1f).

Data Collection

All patients were grouped under respective categories in following parameters:

1. Presence of preoperative hydrocephalous and whether preoperative shunt was placed.
2. Type of dural closure: watertight or not.
3. Presence of meningitis or wound infection in postoperative period.

The interplay of these factors in determining the final outcome of CSF hydrodynamic complications of CSF leak or pseudomeningocoele is shown in the flowchart (►Fig. 2).

Fig. 1 Technique of bone sandwich placement. Craniectomy is performed (A); A piece of Gelfoam cut half way is taken (B) into which bone dust and bits are placed (C,D) which is then placed over craniectomy defect (E,F).

Besides this, other factors which were studied included pathology for which the surgery was performed, preoperative hydrocephalous, and surgical approach.

Statistical Model

The collected data was studied using a binomial logistic regression model, and the rates of CSF leak and pseudomeningocoele were studied for their dependence on parameters including hydrocephalous, dural closure, and infection. The statistical model was checked for applicability and correctly predicted 87% results.

SPSS 24 was used for statistical analysis.

Results

A total of 1135 patients underwent posterior fossa surgery during the period of study from January 1991 to June 2016. Of these, 624 (54.98%) were male and 511 (45.02%) were females. The mean age of the patients was 31.56 years. Among these patients, 843 (74.27%) underwent surgery for neoplastic pathology, 23 (2.03%) underwent auditory brainstem implantation, and rest were operated for posterior fossa decompression (bleeds or infarcts). Retromastoid suboccipital craniectomy approach was performed in 617 (54.36%) patients, whereas 491 underwent unilateral or midline suboccipital craniectomy. Sitting position was employed in 1009 (88.9%) of these procedures and the rest in lateral position (►Fig. 3A–D). There were 24 mortalities in the series.

CSF leak occurred in 77 (6.87%) patients and pseudomeningocoele without CSF leak occurred in 117 (10.3%) patients. Thus, total CSF hydrodynamic complications occurred in 194 (17.09%) patients.

Watertight closure was achieved in 636 (56.03%) patients. Among those with watertight closure, only 26 (4.08% of

Fig. 2 Flowchart depicting interplay of various factors in consideration for cerebrospinal fluid (CSF) hydrodynamic complications.

watertight closure group) patient developed CSF leak, while among those in whom watertight closure was not obtained, 51 (10.23% of non-watertight closure group) patients developed CSF leak. Similarly, among those with watertight closure, pseudomeningocele was seen in 54 (8.49% of watertight closure group) patients and among those without watertight closure pseudomeningocele was seen in 63 (12.62% of non-watertight closure group) patients. Hence, total CSF hydrodynamic complications were 80 (12.57%) in watertight closure group and 114 (22.85%) in non-watertight closure group. While the presence of a watertight dural closure showed a favorable trend toward prevention of CSF hydrodynamic complications, this was not found to be significant (p value = 0.45).

Preoperative hydrocephalous was present in 552 (48.63%) patients. Of these 76 (13.77% of hydrocephalous patients) patients underwent preoperative ventriculoperitoneal (VP) shunt, while 476 did not. Five-hundred eighty-three patients had no preoperative hydrocephalous. Among patients who had hydrocephalous, but were not shunted, 88 (18.49% of this group) patients had CSF hydrodynamic complications. Among the shunted patients, 14 (18.42% of this group) had CSF hydrodynamic complications, while among those with

no preoperative hydrocephalous, 92 (15.78% of this group) had such complications.

Preoperative hydrocephalous, which was not shunted, had significant relation to development of CSF leak (p value 0.04) and highly significant relation to development of CSF hydrodynamic complication considered in total (p value 0.006). In fact, patients with preoperative hydrocephalous which was not shunted were found to be 17.85 times more likely to develop CSF hydrodynamic complication than those with no hydrocephalous or those with preoperative shunt. It would seem that a preoperative CSF diversion procedure may be helpful in reducing the risk of these complications.

Distribution of patients with both closure and hydrocephalous taken into consideration is shown in ►Table 1 and ►Fig. 4a and b.

Thirty-one (2.73%) patients in the series had meningitis or wound infection. Of these, 20 had meningitis and 11 had wound infection. Seventeen (54.84% of this group) patients who had meningitis or wound infection developed CSF hydrodynamic complications. The presence of meningitis or wound infection was another significant factor in development of CSF hydrodynamic complications (p value 0.004).

Fig. 3 Distribution of patients across various parameters. (A) gender, (B) pathology, (C) approach, and (D) position.

Table 1 CSF hydrodynamic complications taking hydrocephalous and dural closure into account

		CSF hydrodynamic complications		
		Yes	No	
Nonshunted hydrocephalous	476	23	164	Watertight Closure
		65	224	Non-watertight closure
Shunt	76	5	32	Watertight closure
		9	30	Non-watertight closure
No hydrocephalous	583	52	360	Watertight closure
		40	131	Non-water tight closure

Abbreviation: CSF, cerebrospinal fluid.

No significant relation was found between CSF leak and/or pseudomeningocele and type of pathology, age group, and surgical approach.

Discussion

Surgical approach to posterior fossa entails either a craniotomy or craniectomy. Posterior fossa surgeries carry risk of complications like CSF leak and pseudomeningocele which presents usually as a cosmetic defect and positional headache and varies in its incidence from 4 to 61% in various sources.⁹⁻¹⁴ These CSF hydrodynamic complications have been postulated to be due to its inherent skull base location, increased dural pulsation, and traction along the suture line. In addition, large distended CSF cisterns which accumulate

after such decompression tend to make the initial lax dural closure tense in turn leading to increased risk of CSF leak. As most patients are bed bound for prolonged time during postoperative period, posterior fossa bears the brunt of increased CSF pressure due to such recumbent position.^{1,7,15} Other risk factors for increased risk of CSF hydrodynamic complications in posterior fossa surgery include large size of tumors especially those greater than 3cm.¹⁶ These factors were not found to be significant by Bayazit et al,¹⁷ though increased blood in the field causes blockade of arachnoid villi with resultant increased CSF pressure which induces leak. Resurgery, meningitis, and craniectomy are other factors implicated in occurrence of CSF leak.^{1,7,13,15-21} Craniectomy is usually preferred for exposure to the posterior fossa as it not only provides widening of the exposure as per the need

Fig. 4 (A and B) Flowcharts depicting cerebrospinal fluid (CSF) hydrodynamic complications taking hydrocephalous and dural closure into account.

but also provides an easy method to approach this small surgical area. Craniotomy, in most posterior fossa approach, would entail careful planning and manoeuvrability as it carries a risk of venous sinus injury and inadequacy of exposure. Also, the surface anatomical bony landmarks show considerable variability in localizing the sinuses. The usage of neuronavigation would discount these risks including a clear defining of the sinus relationship with the bony contours and trajectory and limits of exposure.⁷ However, these facilities may be far and wide in resource-limited centers across the world. There is an ever-present risk of need for widening of postcraniotomy defect as may be imposed by the need for appropriate surgical corridor and exposure. This widening often results in “sinking” bone flap which results in direct dural damage and cosmetic deformity. Dural layer shearing and thinning during craniotomy is a common problem due to dense bone-dural adhesion. This frequently leads to dural tears and potential points for CSF leak during closure.^{1,7} These factors propose favorably toward the traditional preference of craniectomy.

However, most of the recent studies favor craniotomy over craniectomy by weight of the evidence pointing to increased complications of pseudomeningocele and CSF leak occurring with craniectomies.^{1,3–8} The rates of pseudomeningocele and/or CSF leaks in craniectomies have been reported to be as high as 30 to 50%.^{1,7} In fact, they could be even up to 65% in non-watertight closures.⁹ On the contrary, the rates of CSF leak and/or pseudomeningocele in cases where craniotomy was performed have been reported to be 6 to 13% and in cases of non-watertight closures, up to 25%.^{1,7,9} The rates in our series fare favorably, then, even against the cases where craniotomy was performed. Replacement of bone flap after a craniotomy or a cranioplasty acts as a rigid support by tamponading any surge in CSF pressure following postoperative filling up of subarachnoid space with CSF. This tamponade

prevents dural sutures from giving away or a small defect from becoming larger when posterior fossa pressure rises due to cerebellar swelling or when patient strains or coughs. The bone flap also acts as a barrier to CSF leak (although CSF may still find its way along the edges of bone flap, cut margins, and burr-holed portions of the bone flap).^{7,22–24} Bone flap may also act by obliterating any potential dead space for CSF collection. Postoperative pain is found to be less in craniotomies as compared with craniectomy; the dural adhesion to cervical muscle causes traction on the dura which then is transmitted to the posterior fossa causing persistent postoperative pain. This is annulled by the bone flap coming in the way of formation of such adhesion.^{7,25–27} In cases where second surgery is needed, the bone flap acts as a barrier to direct dural breach during cervical muscle dissection.²⁸

Dural closure has often been considered to be an important paradigm in prevention of CSF leak and pseudomeningocele. However, despite a watertight closure and efforts in terms of time and energy, CSF leak is noted in up to 7.7% of patients.^{7,9,29–31}

Rates of failure of primary dural closure in posterior fossa surgeries remain as high as 80 to 90%.⁹ This is due to two reasons. First is dural contraction. This may be consequent either to prolonged surgery and consequent dehydration and alteration in blood supply to dura or to coagulation of dural leaves for surface ooze/bleed.¹⁷ The second is cerebellar swelling due to retraction or manipulation injury.^{7,9,15,32} Dural closure may also fail due to tumor invasion of the dura.^{15,17} Such dural defects when encountered are covered either by a watertight duraplasty or an overlay dural graft. This dural graft/substitute can be autologous, porcine, or synthetic. Nonautologous grafts carry risk of immunogenicity and risk of infections, whereas autologous grafts carry with them, burden of additional incision/exposure, or loss of

Fig. 5 Algorithm for the management of cerebrospinal fluid (CSF) hydrodynamic complications.

supportive fascia at the surgical site.^{7,9} Allografts have been reported to have a slight edge over autografts in preventing CSF hydrodynamic complications. Danish et al reported CSF hydrodynamic complications in 10.7% of allografted patients and in 13.3% of autografted ones.¹⁰ We preferred the autologous fascia and fat for all our patients. However, G-patch and tissue glue were used to reinforce the overlay graft as the need dictated. On this point, we note that usage of tissue glue has always been implicated in preventing fibroblast migration and thereby hindering the healing process.¹⁵ However, as we have seen, the fastidiousness of dural closure as a factor affecting the occurrence of CSF leak/pseudomeningocele has been widely contested in literature.^{1,7,9}

Treatment of hydrodynamic complications of posterior fossa surgery includes conservative management in form of head elevation, acetazolamide, and compression for bandage for at least 3 days. In cases where the conservative management fails, lumbar drainage at the rate of 10 mL/h for minimal of 5 days to maximum of 10 days may be employed. If the above two measures fail, surgical repair is the final resort.^{15,17} In our series, when the patients were noted to have pseudomeningocele, imaging was done to check for hydrocephalous. If the patient had hydrocephalous, a VP shunt was performed, else a lumbar drain was inserted. Both these procedures were done in conjunction with a compression bandage. In cases of CSF leak, wound closure was performed, in addition (→Fig. 5).

Our technique involves a craniectomy, with or without watertight dural closure. We propose that the Gelfoam in the Gelfoam bone sandwich absorbs any initial CSF microleaks and swells up, much similar to its hemostatic mechanism and creates a tamponade effect aided by the bone chips and dust in the sandwich. Furthermore, bone chips and bone dust sandwiched between the sheets of Gelfoam also provide scaffolding for volume sealing effect, obliterating the dead spaces and thus resulting in an effect similar to bone flap replacement after craniotomy. It is our belief that this is responsible for lower rates of CSF hydrodynamic complications in our series compared with rates reported for craniectomies which are comparable to craniotomy.

Conclusion

Our technique of keeping a sandwich of bone bits and dust between sheets of Gelfoam as overlay graft provides an effective, cheap, and readily available alternative way to reduce CSF hydrodynamic complications.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Funding

No funding was received for this research.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or nonfinancial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

References

- Legnani FG, Saladino A, Casali C, et al. Craniotomy vs. craniectomy for posterior fossa tumors: a prospective study to evaluate complications after surgery. *Acta Neurochir (Wien)* 2013;155(12):2281–2286
- DiMeco F, Li KW, Casali C, et al. Meningiomas invading the superior sagittal sinus: surgical experience in 108 cases. *Neurosurgery* 2004;55(06):1263–1272, discussion 1272–1274
- Bryce GE, Nedzelski JM, Rowed DW, Rappaport JM. Cerebrospinal fluid leaks and meningitis in acoustic neuroma surgery. *Otolaryngol Head Neck Surg* 1991;104(01):81–87
- Fishman AJ, Hoffman RA, Roland JT Jr, Lebowitz RA, Cohen NL. Cerebrospinal fluid drainage in the management of CSF leak following acoustic neuroma surgery. *Laryngoscope* 1996;106(08):1002–1004
- Fishman AJ, Marrinan MS, Golfinos JG, Cohen NL, Roland JT Jr. Prevention and management of cerebrospinal fluid leak following vestibular schwannoma surgery. *Laryngoscope* 2004;114(03):501–505
- Nutik SL, Korol HW. Cerebrospinal fluid leak after acoustic neuroma surgery. *Surg Neurol* 1995;43(06):553–556, discussion 556–557
- Gnanalingham KK, Lafuente J, Thompson D, Harkness W, Hayward R. Surgical procedures for posterior fossa tumors in children: does craniotomy lead to fewer complications than craniectomy? *J Neurosurg* 2002;97(04):821–826
- Hoffman RA. Cerebrospinal fluid leak following acoustic neuroma removal. *Laryngoscope* 1994;104(1 Pt 1):40–58
- Narotam PK, Qiao F, Nathoo N. Collagen matrix duraplasty for posterior fossa surgery: evaluation of surgical technique in 52 adult patients. *Clinical article. J Neurosurg* 2009;111(02):380–386
- Danish SF, Samdani A, Hanna A, Storm P, Sutton L. Experience with acellular human dura and bovine collagen matrix for duraplasty after posterior fossa decompression for Chiari malformations. *J Neurosurg* 2006;104(1, Suppl):16–20
- Moskowitz SI, Liu J, Krishnaney AA. Postoperative complications associated with dural substitutes in suboccipital craniotomies. *Neurosurgery* 2009;64(3, Suppl):ons28–ons33, discussion ons33–ons34
- Parízek J, Mericka P, Nemecek S, et al. Posterior cranial fossa surgery in 454 children. Comparison of results obtained in pre-CT and CT era and after various types of management of dura mater. *Childs Nerv Syst* 1998;14(09):426–438, discussion 439
- Santamarta D, Blázquez JA, Maillo A, Muñoz A, Caballero M, Morales F. [Analysis of cerebrospinal fluid related complications (hydrocephalus, fistula, pseudomeningocele and infection) following surgery for posterior fossa tumors]. *Neurocirugia (Astur)* 2003;14(02):117–126
- Steinbok P, Singhal A, Mills J, Cochrane DD, Price AV. Cerebrospinal fluid (CSF) leak and pseudomeningocele formation after posterior fossa tumor resection in children: a retrospective analysis. *Childs Nerv Syst* 2007;23(02):171–174, discussion 175
- Kshetty VR, Lobo B, Lim J, Sade B, Oya S, Lee JH. Evaluation of non-watertight dural reconstruction with collagen matrix onlay graft in posterior fossa surgery. *J Korean Neurosurg Soc* 2016;59(01):52–572
- Magliulo G, Sepe C, Varacalli S, Fusconi M. Cerebrospinal fluid leak management following cerebellopontine angle surgery. *J Otolaryngol* 1998;27(05):258–262
- Bayazit YA, Celenk F, Duzlu M, Goksu N. Management of cerebrospinal fluid leak following retrosigmoid posterior cranial fossa surgery. *ORL J Otorhinolaryngol Relat Spec* 2009;71(06):329–333
- Dawood A, Syed ZHS, Amir M. Frequency of CSF leak after craniotomy for paediatric brain tumors. *Pak J Neurol Surg* 2015;19(03):160–165
- Brennan JW, Rowed DW, Nedzelski JM, Chen JM. Cerebrospinal fluid leak after acoustic neuroma surgery: influence of tumor size and surgical approach on incidence and response to treatment. *J Neurosurg* 2001;94(02):217–223
- Selesnick SH, Liu JC, Jen A, Newman J. The incidence of cerebrospinal fluid leak after vestibular schwannoma surgery. *Otol Neurotol* 2004;25(03):387–393
- Stieglitz LH, Wrede KH, Gharabaghi A, et al. Factors affecting postoperative cerebrospinal fluid leaks after retrosigmoidal craniotomy for vestibular schwannomas. *J Neurosurg* 2009;111(04):874–883
- Hayward R. Posterior fossa craniotomy: an alternative to craniectomy. *Pediatr Neurosurg* 1999;31(06):330
- Kurpad SN, Cohen AR. Posterior fossa craniotomy: an alternative to craniectomy. *Pediatr Neurosurg* 1999;31(01):54–57
- Ogilvy CS, Ojemann RG. Posterior fossa craniotomy for lesions of the cerebellopontine angle. Technical note. *J Neurosurg* 1993;78(03):508–509
- Harner SG, Beatty CW, Ebersold MJ. Impact of cranioplasty on headache after acoustic neuroma removal. *Neurosurgery* 1995;36(06):1097–1099, discussion 1099–1100
- David KM, Casey AT, Hayward RD, Harkness WF, Phipps K, Wade AM. Medulloblastoma: is the 5-year survival rate improving? A review of 80 cases from a single institution. *J Neurosurg* 1997;86(01):13–21
- Wazen JJ, Sisti M, Lam SM. Cranioplasty in acoustic neuroma surgery. *Laryngoscope* 2000;110(08):1294–1297
- Chowdhury FH, Goel A, Haque R, Islam S, Sarkar MH, Kawsar KA. Bony reconstruction by reposition of bony chips in suboccipital craniectomy. *Neurol India* 2010;58(04):634–636
- Munshi I, Frim D, Stine-Reyes R, Weir BK, Hekmatpanah J, Brown F. Effects of posterior fossa decompression with and without duraplasty on Chiari malformation-associated hydromyelia. *Neurosurgery* 2000;46(06):1384–1389, discussion 1389–1390
- Parízek J, Měrická P, Husek Z, et al. Detailed evaluation of 2959 allogeneic and xenogeneic dense connective tissue grafts (fascia lata, pericardium, and dura mater) used in the course of 20 years for duraplasty in neurosurgery. *Acta Neurochir (Wien)* 1997;139(09):827–838
- Roberti F, Sekhar LN, Kalavakonda C, Wright DC. Posterior fossa meningiomas: surgical experience in 161 cases. *Surg Neurol* 2001;56(01):8–20, discussion 20–21
- Kaufman HH, Carmel PW. Aseptic meningitis and hydrocephalus after posterior fossa surgery. *Acta Neurochir (Wien)* 1978;44(3-4):179–196