Acta Neurochir (2013) 155:2281–2286
DOI 10.1007/s00701-013-1882-y

CLINICAL ARTICLE - BRAIN TUMORS

Craniotomy vs. craniectomy for posterior fossa tumors: a prospective study to evaluate complications after surgery

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Received: 20 February 2013 / Accepted: 6 September 2013 / Published online: 29 September 2013

Abstract
Background Posterior fossa surgery traditionally implies permanent bone removal. Although suboccipital craniectomy offers an excellent exposure, it could lead to complications. Thus, some authors proposed craniotomy as a valuable alternative to craniectomy. In the present study we compare post-operative complications after craniotomy or craniectomy for posterior fossa surgery.
Methods We prospectively collected data for a consecutive series of patients who underwent either posterior fossa craniotomy or craniectomy for tumor resection. We divided patients into two groups based on the surgical procedure performed and safety, complication rates and length of hospitalization were analyzed. Craniotomies were performed with Control-Depth-Attachment® drill and chisel, while we did craniectomies with perforator and rongeurs.
Results One-hundred-fifty-two patients were included in the study (craniotomy $n = 100$, craniectomy $n = 52$). We detected no dural damage after bone removal in both groups. The total complication rate related to the technique itself was 7 % for the craniotomy group and 32.6 % for the craniectomy group (<0.0001). Pseudomeningocele occurred in 4 % vs. 19.2 % ($p = 0.0009$), CSF leak in 2 % vs. 11.5 % ($p = 0.006$) and wound infection in 1 % vs. 1.9 % ($p = 0.33$), respectively. Post-operative hydrocephalus, a multi-factorial complication which could affect our results, was also calculated and occurred in 4 % of the craniotomy vs. 9.6 % of the craniectomy group ($p = 0.08$). The mean length of in-hospital stay was 9.3 days for the craniotomy group and 11.8 days for the craniectomy group ($p = 0.10$).
Conclusions The present study suggests that fashioning a suboccipital craniotomy is as effective and safe as performing a craniectomy; both procedures showed similar results in preserving dural integrity, while post-operative complications were fewer when a suboccipital craniotomy was performed.

Keywords Brain tumor · Craniectomy · Craniotomy · CSF leak · Posterior fossa · Pseudomeningocele

Abbreviations

LP	Lumbar puncture
EVD	External ventricular drain
ETV	Endoscopic third-ventriculostomy
CSF	Cerebrospinal fluid
SpD	Spinal drain
VPS	Ventriculo-peritoneal shunt
OR	Operating room

Introduction

Resection of posterior fossa tumors traditionally entails permanent bone removal. Suboccipital craniectomy gives an excellent exposure of posterior fossa structures, but it could

We presented this work as an e-poster at the annual meeting of the European Association of Neurosurgical Societies (EANS) Bratislava October 24–27 2012.

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lead to several complications [3]. The CSF leak ranges from 4 to 17 % across different craniectomy series [2, 6, 7, 11, 13, 17], while pseudomeningocoele has been reported to occur more frequently after craniectomy rather than after craniotomy [8].

In this study we compared two cohorts of patients operated on by two senior neurosurgeons for posterior fossa tumors through either complete bone removal (craniectomy) or craniotomy (followed by bone flap fixation), in order to assess safety and complication rates of each technique.

Materials and methods

This single-center study started in January 2006 as a service evaluation and enrollment stopped in September 2009. All patients operated on for posterior fossa tumors by the two senior authors (FDM, CLS) within the enrollment period were considered for analysis. We enrolled both adults and children . As previous surgery and tissue damage could affect most of the variables considered in our study, patients who underwent a second operation due to recurrence in the enrollment period were excluded. Furthermore, as we usually do not treat ventricular dilation in patients harbouring a posterior fossa lesion before surgical removal unless symptomatic, we also excluded from the analysis 11 patients who were surgically treated preoperatively with a shunt or ETV for a clinically significant hydrocephalus. In fact, these patients would have represented a specific subset of patients not comparable to the others in terms of the complications analyzed in the present study. Clinical notes, along with both preoperative and postoperative imaging of the remaining patients were prospectively collected and analyzed. Whenever the neuronavigation system was available, we preferred to perform a craniotomy rather than a craniectomy, because our feeling, based on previous clinical observation, was that bone flap replacement is associated with fewer complications. Craniectomy was performed when the neuronavigation system was not available for any reason. We defined patients undergoing craniotomy as Group #1, while those undergoing craniectomy were labeled as Group #2.

At the end of each operation, the surgeon was required to complete a standardized postprocedure form comprising location and possible nature of the lesion, the surgical technique adopted, the time necessary to expose the dura, the number of dural tears after bone removal (if any), the quality of the dural closure (complete vs. incomplete) and the use of dural substitutes (if any). Postoperative complications (hydrocephalus, pseudomeningocele, CSF leak and wound infection) and histopathology were recorded on a second specific form, which was attached to the patient's clinical file. Follow-up period was six months.

Hydrocephalus was diagnosed through both clinical and radiological criteria (i.e., progressive cognitive impairment with evidence of neuroradiological ventricular enlargement). Pseudomeningocele was reported only if clinically significant (i.e., symptomatic to the patient or presenting with evident neck swelling); an incidental neuroimaging finding was not considered as a complication. A CSF leak was defined as clear fluid discharge from a surgical incision. Skin discharge or dehiscence associated to a positive microbiology culture was labeled as a wound infection. The CSF infection was usually confirmed by a positive microbiological isolation, obtained from an LP or an EVD sample. The treatment provided for each complication was also recorded. In all cases of CSF leak, a wound revision was performed and extra stitches were put on the dehiscence site. Targeted antibiotic therapy was performed in case of wound infection.

Surgical procedure

During surgery, all patients were given high doses of dexamethasone (up to 0.5 mg/kg/day), which was progressively tapered postoperatively depending on tumor histopathology, neurological performance, and perilesional edema. All patients received a first dose (1 g for adults; 25 mg/kg for children) of intravenous cefazolin at induction, followed by subsequent doses every 3 h in case of prolonged procedures (500 mg for adults; 12.5 mg/kg for children). In the majority of cases, patients were placed in the semisitting position, otherwise they were positioned prone. Intraoperative positioning of a lumbar drainage was never required. Whenever available, a post-gadolinium volumetric T1 weighted MRI and a volumetric CT scan were loaded and matched into a neuronavigation system (Stealth Station, Medtronic Inc., Minneapolis, MN, USA), which was used intraoperatively to verify exactly venous sinuses location and bone thickness. When neuronavigation was available, a craniotomy was performed.

Craniotomy was carried out using a high-speed air-drill Control-Depth-Attachment® (CDA) (The Anspach Effort®, Inc., Palm Beach Gardens, FL, USA) without performing burr holes, following a slightly modified, previously described, technique [5]. With the aid of the neuronavigation system, the outer table of the bone flap was cut over the margins of the venous sinus bone projection, and then the cut was extended through the cancellous bone with the drill, going down to the inner table, which was left intact (Fig. 1a). The full thickness of the inner table was then chiselled away with a thin blade osteotome (Lexer Mini Osteotome, Aesculap, Tuttlingen, Germany) (Fig. 1b). Finally, the dura was carefully stripped with a periosteal elevator and the bone flap was removed (Fig. 1c). Small holes were drilled trough the full thickness of the bone flap and the corresponding areas of the native cranium in at least three locations. At the end of the operation, the bone flap was replaced and secured with 0 silk sutures (Fig. 1d) or titanium plates and self-taping screws. No

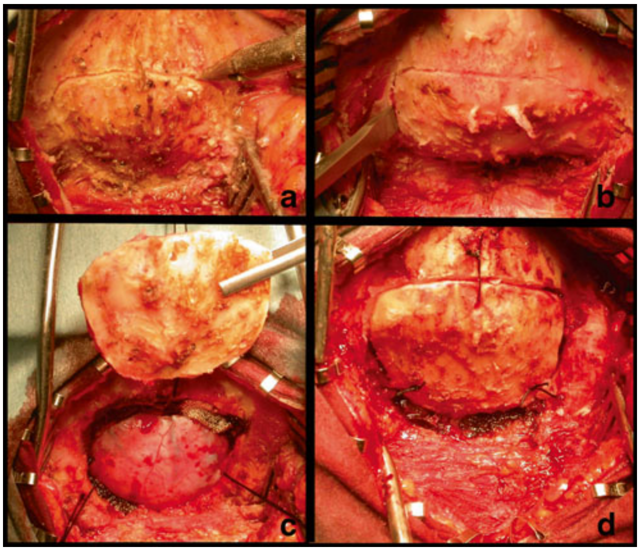


Fig. 1 Intraoperative pictograph showing our surgical technique. **a** a thin osteotomy is performed with the CDA through the outer table and the cancellous bone; **b** complete osteotomy through the inner table is carried out with a thin bladed chisel; **c** dural strip and bone flap creation; **d** repositioning of the bone flap, fixed with thick silk stitches

manipulates, bone dust, synthetic bone or other devices were used. When a lateral suboccipital craniotomy was performed and mastoid air cells were opened, the inner layer of the bone was left in place and removed under direct microscopic vision after bone flap elevation (Fig. 2).

Posterior fossa craniectomy was accomplished by placing three or four burr holes with a perforator (The Anspach Effort®, Inc., Palm Beach Gardens, FL, USA) equipped with a protective guard; the remaining bone was removed with rongeurs. For all craniotomy and craniectomy cases, the dura mater, the cervical muscles and the fascia were closed in layers using absorbable sutures. Tabotamp® (Ethicon SARL, Neuchatel, Switzerland) and human fibrin glue (Tissucol, Baxter Healthcare, Deerfield, IL, USA) were applied in all cases to facilitate dural closure healing. A running absorbable intradermic suture was used in any case to close the skin. A pressure dressing was not routinely applied to the wound postoperatively. Both craniotomies and craniectomies were preferably performed in the semisitting position, unless contraindicated by a significant cardiac shunt (detected preoperatively by air contrast trans-cranial Doppler).

Statistical analysis

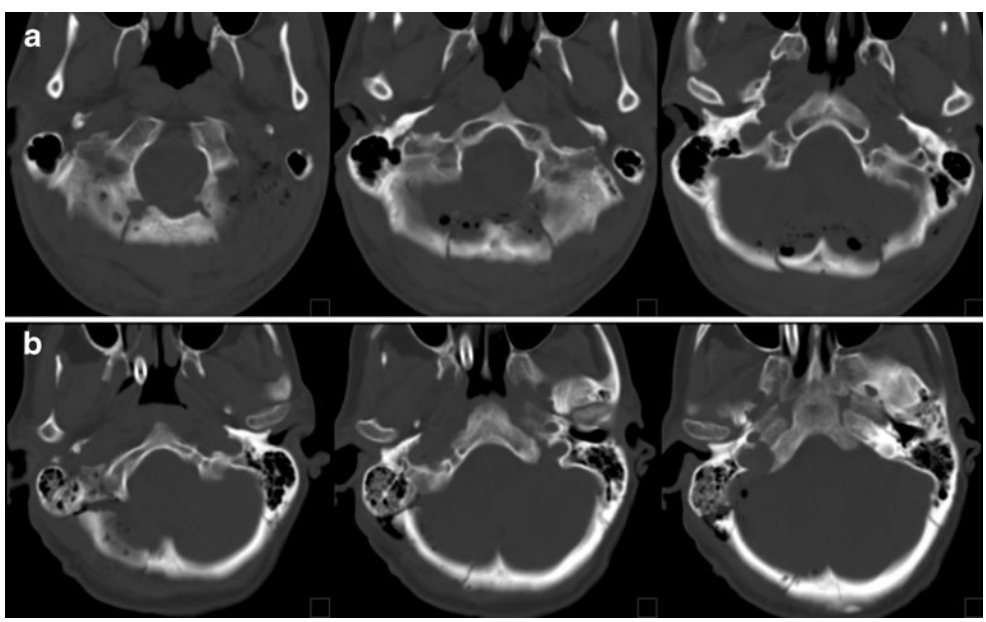
Statistical analysis of the complication rates of each group was performed using a Student's t test, $p \leq 0.05$ was considered as significant. Statistical analysis was performed using SPSS software, version 8.0 for Windows (SPSS, Inc., Chicago, IL, USA).

Results

A consecutive series of 172 patients were operated on for posterior fossa tumors by two senior surgeons (FDM, CLS) within the enrollment period. Nine patients were excluded because of a second operation due to recurrence. Similarly, 11 patients with clinically significant hydrocephalus treated with shunt placement prior to surgery were also excluded. Clinical notes, along with both preoperative and postoperative imaging of the remaining 152 patients (56 males and 96 female) were prospectively collected and analyzed. All patients completed the six months follow-up period.

Craniotomy was performed on 100 patients, craniectomy on 52. Patient mean age was 39.3 years (ranging from 5 to

Fig. 2 Post-operative bone window CT scan showing a midline (**a**) and a lateral retrosigmoid (**b**) suboccipital craniotomy



81 years, SD±18.6), and 46 years (ranging from 13 to 81 years, SD±15.6) in the group 1 and 2, respectively (Table 1). Sixty-eight patients (68 %) underwent surgery for an extra-axial tumor in group 1, and 34 (65.4 %) in group 2; the reason for surgery was an intra-axial tumor in 32 patients (32 %) and 18 (34.6 %) in the first and in the second group, respectively (Table 2).

The majority of patients were operated on in the semisitting position (93 craniotomies and 37 craniectomies), and the remainder in the prone position (7 craniotomies and 15 craniectomies). We never put a lumbar drainage intraoperatively and we never experienced any major complication related to air embolism.

The average operating time (from skin incision to dural exposure) was 25 min (ranging from 15 to 40 min), in both groups. The two surgical techniques were also comparable in terms of dural damage during bone removal, since no dural tear was reported in any case.

Dural closure was intraoperatively deemed incomplete, therefore, requiring additional means of repairing, in three (3 %) and six (11.6 %) patients of the craniotomy and the craniectomy group, respectively. In three patients of the first group and in two patients of the second group, a dural substitute (DuraGen®, Integra LifeSciences Corporation, Plainsboro, NJ, USA) was applied on top of the original dura, in addition to Tabotamp® (Ethicon SARL, Neuchatel, Switzerland) and fibrin glue. In the other four patients of the second group, a duraplasty was performed using bovine pericardium (TutoPatch, Tutogen Medical GmbH, Neunkirchen, Germany). Nonetheless, three out of six patients (50 %) in the craniectomy group with incomplete dural closure developed pseudomeningocele.

The overall complications rate was 7 % in group 1, and 32.6 % in group 2 ($p<0.0001$). A CSF leak occurred in two patients (2 %) in the first group and six patients (11.5 %) in the second group ($p=0.006$); Pseudomeningocele was noted in four patients (4 %) in the first group, and in ten patients (19.2 %) in the second one ($p=0.0009$). There was only one wound infection in each group ($p=0.33$). Hydrocephalus requiring ventricular drainage complicated the postoperative course in four (4 %) and fve (9.6 %) patients in the craniotomy and craniectomy group, respectively ($p=0.08$). Besides ventricular drainage for hydrocephalus, none of the patients required second surgery for dural repair in both groups. Complication rates and type of complication for the two groups are summarized in Tables 3 and 4.

The mean in-hospital length of stay was 9.3 days (SD±8.6, median 7 days) for the craniotomy group (ranging from 3 to 56 days) and 11.8 days (SD±16.8, median: 7 days) for the craniectomy group (ranging from 3 to 120 days) ($p=0.10$) (Table 5).

Table 1 Patients' features

	N° of patients (%)	
	Craniotomy	Craniectomy
Patients	100	52
Male	48 (48)	18 (34,6)
Female	52 (52)	34 (66,4)
Age mean (years)	39,3	46
Range	5–81	13–81
SD	±18,6	±15,6

Table 2 Tumor histotypes

Tumor type	Craniotomy (%)	Craniectomy (%)
Schwannoma	33 (33)	21 (40,4)
Meningioma	24 (24)	12 (23,1)
Epydermoid cyst	11 (11)	1 (1,9)
Hemangioblastoma	8 (8)	4 (7.7)
Metastasis	6 (6)	6 (11,6)
Low-grade glioma	6 (6)	2 (3,8)
High-grade glioma	7 (7)	1 (1,9)
Medulloblastoma	2 (2)	3 (5,8)
Ependymoma	3 (3)	2 (3,8)

Discussion

Surgical approach to posterior fossa lesions traditionally implied permanent bone removal [3]. Although suboccipital craniectomy provides an excellent access to this region, this approach is associated with a theoretical, postopertive risk of damaging the cerebellum, which remains relatively unprotected. In 1974 Yasargil and Fox [19] described a technique to fashion a bone flap, which could be put back in place at the end of the procedure; the bone was cut through with a Gigli saw, after performing a few burr holes. Ogilvy and Ojemann further improved this technique, by using high speed instrumentation, such as an air-powered drill equipped with a diamond-tipped bit [14]. Over the years quite a few technical

Table 3 Postoperative complications

Complication	N° of complications (%)		p value
	Craniotomy	Craniectomy	
Pseudomeningocele	4 (4)	10 (19.2)	0.0009
CSF leak	2 (2)	6 (11.5)	0.006
Wound infection	1 (1)	1 (1.9)	0.33
Total	7 (7)	17 (32.6)	<0.0001
Hydrocephalus	4 (4)	5 (9.6)	0.08

Table 4 Treatment of postoperative complications

Complications *Treatment*	Craniotomy	Craniectomy
Pseudomeningocele	4	10
Transcutaneous needle aspiration + SpD + pressure dressing	*0*	*1*
Transcutaneous needle aspiration + LP + pressure dressing	*1*	*1*
Transcutaneous needle aspiration + pressure dressing	*2*	*8*
Pressure dressing only	*1*	*0*
CSF leak	2	6
Stitches + SpD + pressure dressing	*2*	*6*
Hydrocephalus	4	5
VPS	*4*	*5*

Italicized value is the treatment

procedures have been described to better access and reconstruct the posterior fossa [9, 10, 16, 18]. Nowadays modern craniotomies are widely used and they have almost completely replaced the Gigli saw as key tools to perform craniotomies. However, craniotomies have not solved several major problems that may occur while performing a craniotomy. First, surgical access to the posterior fossa (in particular for cerebello-pontine angle lesions) remains challenging per se. Second, bony gaps created by the craniotome along with burr holes are often a cause of cosmetic deformities, secondary to bone flap "sinking" [1, 12, 15]. Lastly, injury to venous structures may still occur when the craniotomy extends above or near dural sinuses. In order to overcome these problems we developed an alternative craniotomy technique, which is characterized by the use of a micro-oscillating saw and an osteotome [4]. This procedure was initially intended to gain access to the anterior part of the skull base, in patients harbouring craniofacial tumors [5]. Moving from our positive experience with this technique for that subset of lesions (where we observed very few cases of dural tearing and none of sinus injury), we then decided to perform every supratentorial craniotomy with the above technique; lately, we extended the indications of this technique even to the posterior fossa surgery. We improved the previously described surgical technique by using a high-speed air drill equipped with a CDA® micro tip, instead

Table 5 In-hospital length of stay

	Craniotomy	Craniectomy
Days in hospital (mean)	9,3	11,8
Days in hospital (median)	7	7
Range	3–56	3–120
SD	±8.6	±16.8
p value	0.10	

of the oscillating saw. The CDA® can be easily handled as a regular pencil, allowing the neurosurgeon to "draw" any shape of craniotomy.

In the present study, which was planned as a service evaluation, we compared two techniques (craniotomy vs. craniectomy) to access the posterior fossa in a consecutive series of 152 patients harbouring either an intra-axial or extra-axial tumor. To minimize any possible confounding factors (e.g., different surgeons with varying degrees of surgical expertise, different surgical tools, different operating room (OR) settings and postoperative management), we prospectively collected all patients operated on by only two senior neurosurgeons (FDM, CLS) from the same neurosurgical team in a limited period of time (January 2006 to September 2009).

In our series there was no significant difference when comparing the average time from skin incision to dural exposure between the craniotomy and the craniectomy series.

One of the advantages of performing a craniectomy is the direct and continuous visualization of the dura mater while removing each bone chip. The thin dura layer can be progressively and gently stripped from the bone, thus preventing dural damage, which could make it difficult or impossible to get a watertight closure of the native dura at the end of the procedure. In fact, no dural tears were detected after bone removal among the craniectomy series. On the contrary, the use of a craniotome could potentially lead to accidental dural stripping. However, in this series, we never tore the dura while fashioning a craniotomy and removing the bone flap for posterior fossa surgery. As previously reported, this could be due to the so-called "wedging effect" of the chisel by which the bone flap is detached from the skull, preventing the chisel from penetrating too deeply, and, at the same time, the dura itself is pushed away from the bone inner table [5].

Our results confirmed that dural integrity is very important for successful posterior fossa surgery, since 50 % of patients with incomplete dural closure in the second group developed pseudomeningocele, even if a dural substitute was used. In our series the number of patients with incomplete native dural closure is very small, but it seems to be an independent risk factor for pseudomeningocele.

Statistical analysis of our results revealed that the complication rate was smaller in the craniotomy group as compared to the craniectomy group (7 % vs. 32.6 %, $p<0.0001$).

Looking at a single complication rate, pseudomeningocele was significantly more frequent ($p=0.0009$) when a craniectomy was performeten10 patients, 19.2 % vs. four patients, 4 %). This finding confirms what was previously reported in a pediatric cohort study by Gnanalingham et al. [8]. They suggested that the bone flap acts as a rigid support over the dural closure, so that dural sutures are not torn out by postoperative subarachnoid CSF refill or raised pressure within the posterior fossa. In this way, any small defect along the dural closure will not enlarge, and CSF is less likely to leak out and collect in the subcutaneous plains, or flow out of the skin. In addition, we agree that the repositioned bone flap could serve as a natural anatomic support for early reattachment of the neck muscle layer; in this way, it is less likely for CSF to collect in a deep dead space between the dura and the muscles [8]. Furthermore, our technique does not require any burr hole to perform a craniotomy and bone loss is also minimal.

In our experience, CSF leak occurred in two (2 %) and six (11.5 %) patients in group 1 and 2, respectively ($p=0.006$). At a further analysis of these data, we found tha at CSF leak was almost invariably a consequence of pseudomeningocele (one case in the first group and six cases in the second group). Interestingly, a CSF leak without pseudomeningocele was recorded only in one case in the craniotomy group.

In addition, we recorded the occurrence of postoperative hydrocephalus requiring ventricular drainage to verify the common belief that suboccipital craniectomy could prevent secondary hydrocephalus due to cerebellar swelling. In our experience we never needed to remove the bone flap for increased intracranial pressure, unless hemorrhagic or ischemic complications occurred. Possibly, the perioperative administration of steroids, adequate tumor debulking, and correct opening of the subarachnoid cysternal space may prevent postoperative cerebellar swelling. In fact, we did not find a statistically significant difference in postoperative hydrocephalus between the two groups (4 % and 9.6 %, respectively, $p=0.08$). This may reflect the multifactorial origin of hydrocephalus and its association with other variables, which were not considered in the present study (e.g.. patient age, intra-operative or post-operative hemorrhagic events, tumor histopathology, etc.), rather than with the type of craniotomy performed.

Mean in-hospital length of stay was 9.3 days and 11.8 days in the first and second group, respectively. This difference was not statistically significant ($p=0.10$), although pseudomeningocele was more common in the craniectomy group. A possible explanation for this may lie in the fact that pseudomeningocele treatment (by CSF percutaneous needle aspiration and pressure dressings) did not require hospitalization. On the other hand, hydrocephalus treatment might have prolonged hospitalization, but since its incidence was comparable in the two groups, it did not affect the mean in-hospital length of stay.

Conclusions

Craniotomy and craniectomy are two widely adopted techniques to access the posterior fossa. Our data suggest that craniotomy is associated with fewer postoperative complications, such as pseudomeningocele and a subsequent CSF leak, which might be related to the surgical technique itself. Furthermore, in this study we describe a valuable alternative to perform a suboccipital bone flap with no burr holes by means of a high-speed air drill and a chisel. Our technique, or other techniques to perform a craniotomy, might be as effective and safe as craniectomy in preserving dural integrity.

Conflicts of interest None.

Funding No special funding was provided to perform the present study.

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