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Marking Basilar Artery Using Neuronavigation During Endoscopic Third Ventriculostomy: A Clinical Study

Onur OZGURAL[1], Gokmen KAHILOGULLARI[1], Giuseppe CINALLI[2], Umit EROGLU[1], Ihsan DOGAN[1], Eyyub S M AL-BEYATI[1], Murat ZAIMOGLU[1], Agahan UNLU[1]

[1]Ankara University School of Medicine, Department of Neurosurgery, Ankara, Turkey
[2]University of Naples Federico II, Santobono Pausilipon Hospital, Department of Neurosurgery, Naples, Italy

Corresponding author: Onur OZGURAL ✉ onurozgural@yahoo.com

ABSTRACT

AIM: To evaluate the efficacy of using a neuronavigation system for demonstrating the relationship between the basilar artery (BA) and ventricular floor during endoscopic third ventriculostomy (ETV).

MATERIAL and METHODS: Records of 28 patients (16 females and 12 males) diagnosed with obstructive hydrocephalus who had undergone a neuroendoscopic procedure were retrospectively examined. Patient age ranged from 1 to 76 years (median 24.46 years). The BA was marked with using the neuronavigation system in all cases to visualise its relationship to the floor of the third ventricle in real time.

RESULTS: ETV was successfully performed in 28 patients with obstructive hydrocephalus. Of these, 13 (46.4%) patients had a thickened tuber cinereum (TC) membrane and 3 (10.7%) showed lateralization of the BA under the ventricular floor. No contact with the BA or related complications (e.g., major bleeding) was encountered with BA marking by using neuronavigation.

CONCLUSION: Even though thickening of the TC membrane and/or displacement of the BA might be seen otherwise, we describe a new method that combines marking the BA and using neuronavigation to provide greater safety in the area where the ventriculostomy will be performed. This permits clearer orientation for the surgeon which significantly contributes to minimizing surgical morbidity.

KEYWORDS: Basilar artery, Endoscopic, Neuronavigation, Tuber cinereum, Ventriculostomy

INTRODUCTION

Neuroendoscopic surgery is routinely used not only during third ventriculostomy but also during procedures such as cyst fenestration, complex hydrocephalus and tumour biopsy (4,9,19,22,24,36). Such increased use also increases complication rates due to neuroendoscope use, e.g., wrong direction or damage due to the endoscope's direct mechanical impact (25). Therefore, the entire neuroendoscopic procedure from the preoperative period to removal of endoscope after washing- should be well-planned (23,26). Minor haemorrhages may be seen during endoscopic third ventriculostomy (ETV) which usually stop after washing, but major bleeding from the basilar artery (BA) or its branches can result in serious complications and are associated high morbidity and mortality. Therefore, it is essential to obtain precise fenestration in the floor of the ventricle without injuring the BA, and a ventriculostomy is generally performed in the safe zone described before, which is the area between the infundibular recess and in front of the mammillary bodies (14,27,38,41). Nonetheless, anatomical variations in the BA and its branches have been described in the past decade, and other at-risk situations during ETV include the absence of a translucent TC which prevents endoscopic visualisation and localization of the arteries, especially in the elderly (31,34). Integration of neuronavigation during neuroendoscopic procedures can result in a safer procedure with real-time visualisation during

Onur OZGURAL : 0000-0001-5797-4373
Gokmen KAHILOGULLARI : 0000-0001-8137-0510
Giuseppe CINALLI : 0000-0002-7797-8483
Umit EROGLU : 0000-0001-8623-071X
Ihsan DOGAN : 0000-0002-1985-719X
Eyyub S M AL-BEYATI : 0000-0001-6246-4247
Murat ZAIMOGLU : 0000-0001-5330-1251
Agahan UNLU : 0000-0002-2039-8592

ETV. Here, we have evaluated the effectiveness of using a 'navigation-guided safe fenestration zone' by marking the BA in patients undergoing ETV.

MATERIAL and METHODS

Patients and Preoperative Assessment

Medical records of 28 patients diagnosed with obstructive hydrocephalus who had undergone the ETV procedure were retrospectively reviewed. Patient consent form was taken from all patients (form was taken from parents who were under 18 ages). Exclusion criteria included previous ETV procedures, shunt placement, diagnosed complex hydrocephalus, or presence of intraventricular tumours. Three-dimensional gradient-echo (3D-GRE) MR images, acquired at slide thickness of 1 milimeter (mm), were transferred to the neuronavigational system workstation for reconstruction of a three-dimensional model of the patient's head and brain. Neuronavigation used the Brainlab® Cranial 3.0 system. Burr holes to be opened were identified at the classic Kocher's point and their placement was controlled using navigation before the incision was made (Figure 1). A head frame (Mayfield) was used in all patients as part of the navigation system, except in four infants less than 2 years old. The BA was marked using in every patient and was used to reveal the 'neuro-guided safe zone' during fenestration, based on the position of the BA.

Surgical Procedure

Slightly curved incisions were made in the skin and the periosteum and burr holes opened using curved front and back movements such that the trocar could fit (Figure 2). The brain needle was introduced using the navigation system in order to minimise the error margin during initial entry (Figure 3). Variable size of trocar (2.5-5.5 mm) was selected based on previous calculations on MRI. Next, 0-degrees rigid neuroendoscope (The Little Lotta®, Karl Storz SE & Co. KG, Tuttlingen, Germany was inserted into the ventricle under neuronavigation guidance (Figure 4). Next, using neuronavigation, after entering the third ventricle, the floor and the position of the BA were identified and the relationship between artery and TC was established. If a thickened TC and/or displacement of BA were observed, the hole in the ventricle floor was made in the safe area without any major artery, as determined using the navigation system. After completion of the ventriculostomy, the intraventricular region was irrigated for 2-3 minutes and the procedure was completed. The entire procedure lasted between 9-14 minutes for all patients.

RESULTS

Of the 28 patients, 12 were male and 16 were female. Patients' ages ranged between 1-76 years with mean age of 24.46 years; 12 patients were less than 18 years old while 16 patients were older than 18 years. Twenty-four of the 28 patients diagnosed with obstructive hydrocephalus had symptoms of headaches, dizziness, blurred vision, and gait disorder, while 4 patients who were 2 years old or younger presented with discomfort, increase in head circumference, and fontanelle tension. Table I lists patient demographics such as age, gender, symptoms, and complications. The TC was seen as a thick membrane in 13 cases (46.7%; five males and eight females; Figures 5 A, B), while lateral displacement of the BA was seen in three patients (10.7%; two females and one male). Neuronavigation was particularly helpful in these 16 patients as the BA and the area of ventriculostomy could be effectively identified (Figure 6). Table II shows the relationship between BA and TC. That was observable as mild haemorrhage in two patients during the intraoperative period; they were controlled by washing. No contact with the BA or related complications (e.g., major bleeding) occurred under neuronavigation guidance and there were no mortalities.

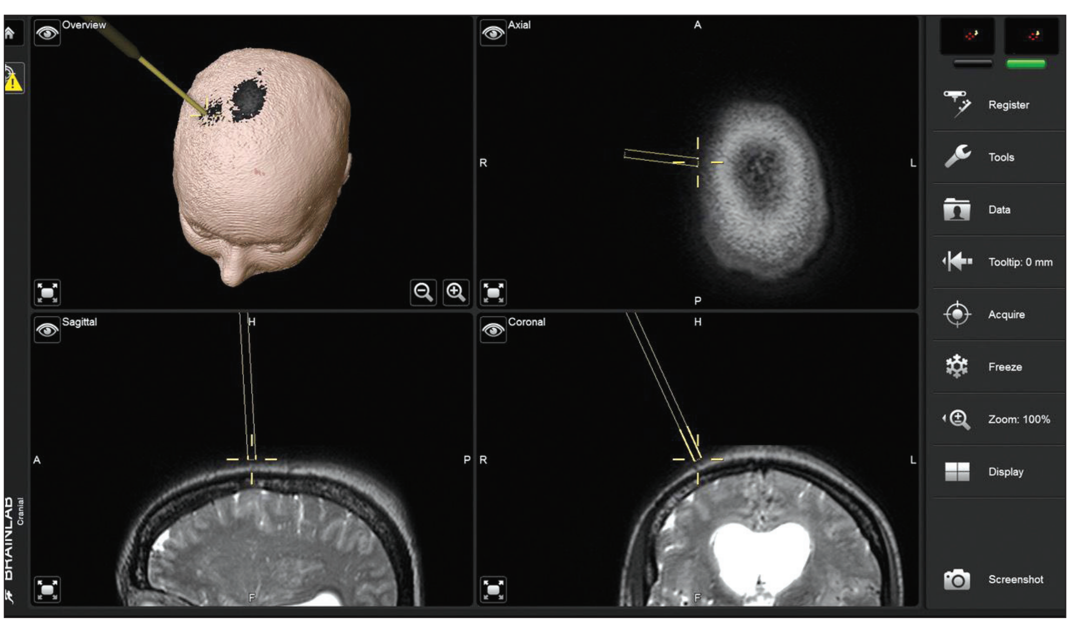

Figure 1: A direct route to the lateral ventricle using the navigation system on MRI.

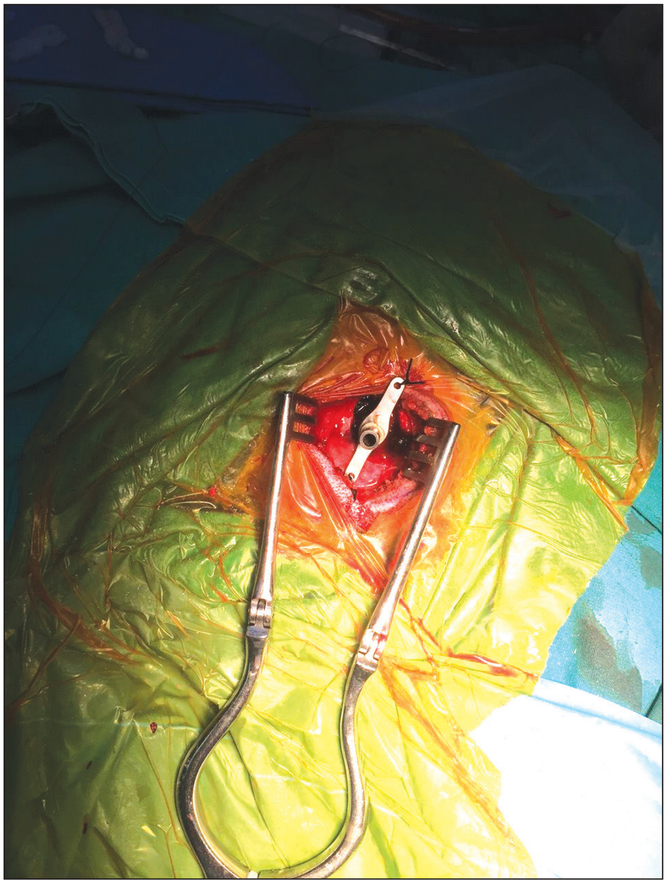

Figure 2: After skin incision and replacement of trocar.

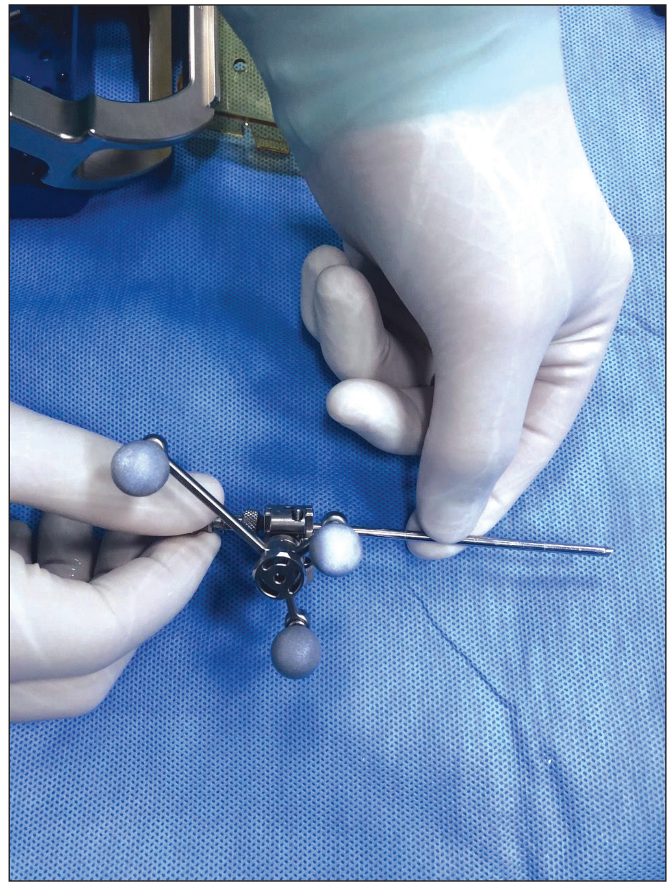

Figure 3: Brain needle with the navigation antenna.

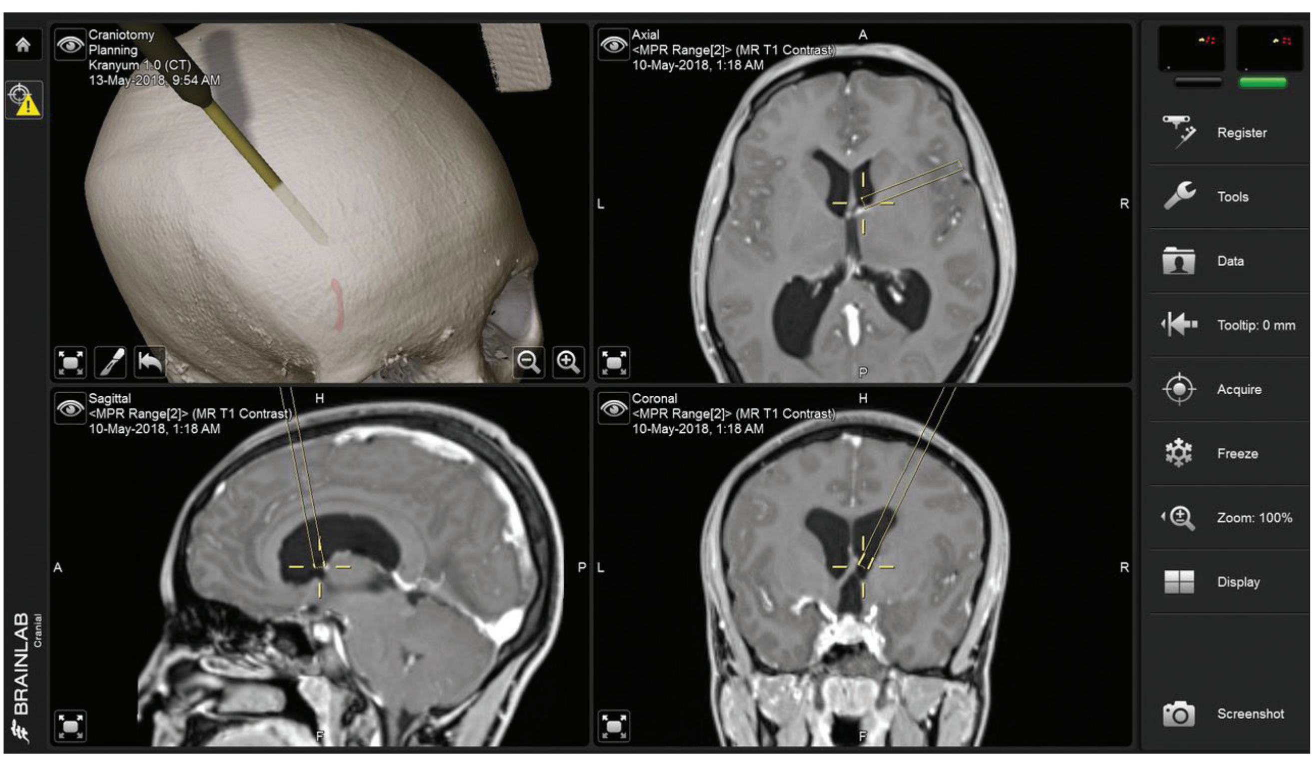

Figure 4: Neuronavigation shows the endoscope after entry in to the ventricle.

Table I: Demographic and Clinical Features of the Patients, and Surgical Complications

Patient No	Age	Sex	Symptom	Complication
1	44	F	HA	-
2	43	F	HA, GD	Mild hemorrhage
3	1	M	FT, IHC	CSF leakage
4	28	F	HA	-
5	36	M	HA, BV	-
6	76	M	HA, GD, D	-
7	25	F	HA	-
8	2	F	FT, IHC	-
9	20	F	HA	Mild hemorrhage
10	32	M	HA, BV	-
11	64	F	HA, GD, D	-
12	17	M	HA	-
13	20	M	HA	-
14	13	F	HA, BV	-
15	10	M	HA	-
16	55	M	HA, GD, BV	-
17	1	F	FT, IHC	CSF leakage
18	1	M	FT, IHC	-
19	5	M	HA	-
20	25	F	HA, GD, D	-
21	8	F	HA, BV	-
22	9	F	HA	-
23	42	F	HA, GD, D	-
24	25	M	HA, GD	-
25	6	F	HA	-
26	39	F	HA, BV	-
27	20	M	HA, D	-
28	18	F	HA, D	-

***F:** Female, **M:** Male, **HA:** Headache, **GD:** Gait disturbance, **D:** Dizziness, **BV:** Blurred vision, **FT:** Fontanelle tension, **IHC:** Increased head circumference, **CSF:** Cerebrospinal fluid.*

Table II: Numbers of Thickened Tuber Cinereum and Displaced Basilar Artery

Gender	Thickened TC	Displaced BA	Total
Male	5	1	6/12
Female	8	2	10/16

***BA:** Basilar artery, **TC:** tuber cinereum.*

DISCUSSION

The use of neuronavigation systems began in the early 2000s and technological improvements since then have increased accuracy rates and safety profile of the procedures, thereby positively affecting prognosis among patients undergoing neurosurgery (1,13). Initially, neuronavigation was used in microscopic transcranial procedures, and as experience was gained, it was adapted for use in transsphenoidal endoscopic procedures (8,40). The use of neuronavigation in intraventricular surgical procedures for hydrocephalus and arachnoid cysts has only recently increased and has been shown to be highly beneficial in patients with particularly complex anatomy (12,20,35,39). We show that it is possible to provide direct and straight entry into the ventricle during the first phase of the procedure by introducing the navigation system to the brain needle. Such a manoeuvre is particularly advantageous in patients with asymmetrical ventricle anatomy. Similar to our experience described here, McMillen et al. have reported that neuronavigation systems were beneficial when used for neuroendoscopic procedures performed on 19 paediatric patients with abnormal ventricular anatomy (28). Hermann et al. have shown that navigation system use was helpful and reliable during electromagnetically-navigated neuroendoscopic procedures in 22 paediatric patients (15). However, in this study, we used head frame fixation rather than a horseshoe headrest, except in patients who were less than 2 years old. In doing so, we eliminated any potential deviation in navigation due to possible movement of the patient. However, unlike the two studies mentioned above, we used neuronavigation as a ‘safe zone guide’ to the floor of the third ventricle floor by marking the BA to avoid major arterial injury.

It is known that the optimal fenestration area in the third ventricle is in the middle of the floor (14,29,41). Brockmeyer has signified that this should be at a point just anterior to the midpoint between the mamillary body and the infundibular recess (5). Posterior fenestration from this point onwards can result in encountering the BA or its major branches. Therefore, entering a little anterior to the midpoint is safer than entering more posteriorly (5). Although there is a translucent area called the ‘safe zone’ in the middle of the TC, Vinas et al. have emphasised that even a very small midline fenestration can cause BA injury, and several studies have identified contact with the tip of the neuroendoscope, laser, or coagulation wire as the major etiological factors of basilar injury (6,16,27,37,41). However, Yildirim et al. reported a case with higher BA location and a thick Lillequist Membrane may have tragic consequences but achieved to make a hole at the floor by retracting BA (43). Given this, it is important to mention here that we used neuronavigation-guided fenestration, where in the BA and its association with the ventricular floor could be visualised in a real time to avoid major arterial bleeding, especially in patients with unusual anatomy.

It is essential and highly important that neuroendoscopic procedures where in the skull is penetrated through a small hole not result in any neural and/or vascular damage while reaching the targeted area (7,30). Therefore, it is better to

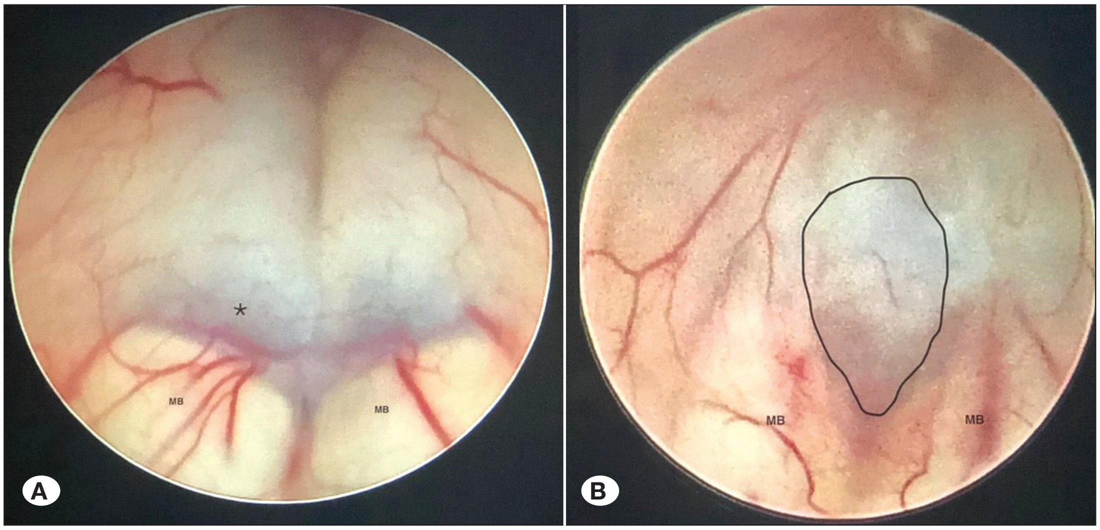

Figure 5: **A)** Intraoperative neuroendoscopic view of thick-blurred tuber cinereum (**MB:** mamillary body, **asterisk (*):** displaced basilar artery). **B)** Intraoperative neuroendoscopic view of thick-blurred tuber cinereum (**black circle:** area of thickened membrane).

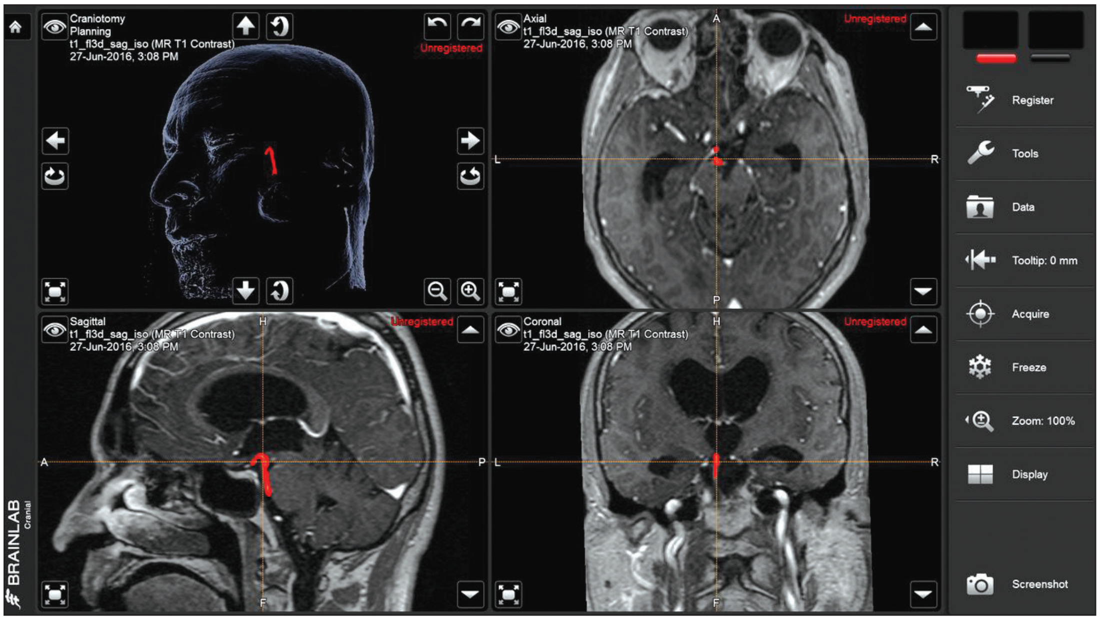

Figure 6: Basilar artery was marked with red on sagittal, axial and coronal MRI sequences, in the lateralised position.

abandon the procedure if there is disorientation, a higher risk of complications such as bleeding, or a thick and opaque ventricular floor without clear visualisation of the anatomy (42). By marking the BA using the navigation system, we achieved greater reliability during routine ventriculostomy procedures. To the best of our knowledge, this is different from the surgical procedures described in literature. Importantly, there was no significant morbidity during the ETV procedure and the minor bleeding in two patients could be controlled by washing.

We were able to easily orient and find the area to be fenestrated because the BA under the TC and its relationship to the floor were visible in real time. This modification will be significant, especially in patients who have a thickened membrane with BA displacement (Figures 7A, B). Thickening of the TC in hydrocephalic patients is not an uncommon anomaly, and especially in long standing hydrocephalus, it may occur a dense membrane by existing type I collagen (11). Therefore, the risk of damage to the BA and the small arteries of the TC is also thought to be higher as they are often not visible through the opaque floor (18). Rohde and Gilsbach have reported a 16% incidence of in 25 hydrocephalic patients (33), while Iaccarino et al. found it in 11 of 23 (48%) ETV patients (18). Another study, Etus et al. found 33.1% thickened membrane between 455 meningomyelocele patient who were performed ETV (10). In our study, 13 patients (46.7%) had a thickened membrane such that the BA could not be visualised.

As mentioned above, an important complication of neuro-endoscopic procedures is bleeding and the most concerning is that from the BA and its branches (17). The rate of bleeding ranges between 0-8.5% with reported significant bleeding rate of 4% and basilar type bleeding rate of 0.2% (2,3,21,32). Horsburgh et al. have analysed axial MR images and state that

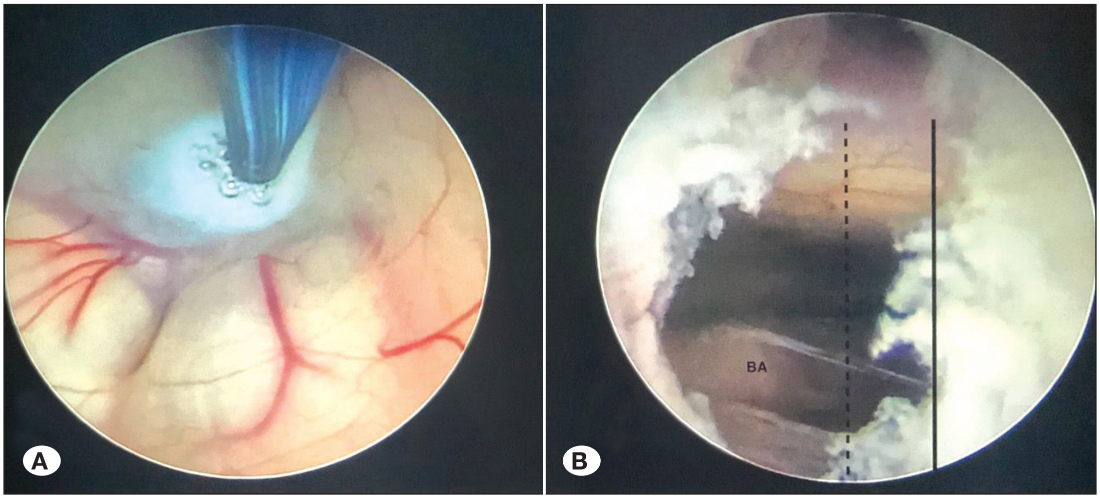

Figure 7: A) Navigation-guided safe zone area, entry pint selected to avoid injury to the left-sided basilar artery **B)** Left-sided basilar artery seen after fenestration, black dotted line shows the midline of floor, black line shows where fenestration had begun on to the floor (**BA:** Basilar artery).

in 12% of the patients, the basilar tip was in close proximity to the mamillary bodies, and that it was located either in front, under, or behind. Additionally, midsagittal MRI views showed that in 10% of the patients, the BA either touched or was within 1 mm of the under-surface of the TC; such a position carries significant risk of potential injury during ETV (17). Another study by Zhang et al. that included 162 MRI angiography images found that displacement of the BA was seen more frequently in men than in women and that it increased with age (44). In contrast, two of the three patients with BA displacement were female in our series. Thus, as it is apparent that ETV in patients with displacement of the BA and its branches is risky, such risk can be eliminated as much as possible by visualising the BA and its branches in real time during the procedure.

Despite the above, there are a few limitations to this study. The small sample size is one, but comparative studies with a greater number of patients will help verify the observations made here. One of the disadvantages of the ETV procedure is prolonged procedure time because the surgeon holds the neuroendoscope with one hand and any increase in tremor would lead to higher morbidity rates. Thus, it is important to perform the procedure without any disruptions and with the entire team functioning flawlessly.

CONCLUSION

We suggest that marking the BA by using neuronavigation during ETV can help in identifying the ‘navigation-guided safe zone’, especially in patients with thickened TC and/or displaced BA anatomy, as it provides better orientation and a superior safety profile.

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