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RESULTS OF VENTRICULOPERITONEAL SHUNT SURGERY USING ELECTROMAGNETIC AND OPTICAL NAVIGATION: EXPERIENCES IN 31 PATIENTS

ELEKTROMANYETİK VE OPTİK NAVİGASYON KULLANILARAK YAPILAN VENTRİKÜLOPERİTONEAL ŞANT CERRAHİSİNİN SONUÇLARI: 31 HASTADAKİ DENEYİMLER

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ABSTRACT

Objective: The ventriculoperitoneal (VP) shunt procedure is frequently performed in the field of neurosurgery to treat pathologies such as normal-pressure hydrocephalus, infection, trauma, or VP shunt dependency after subarachnoid haemorrhage. Although the precise impact of ventricular catheter placement on shunt dysfunction remains not fully elucidated, it is well established that a shunt catheter bypassing the ventricle will lead to shunt dysfunction shortly after placement. Therefore, navigation-assisted shunt surgery gains significance in order to reduce the number of cannulation attempts and for inserting the ventricle catheter in the proper position compared to free hand catheter placement.

Material and Method: This retrospective study enrolled 31 patients who underwent VP shunt placement in two different clinics by two different surgeons using electromagnetic and optical navigation between 2016 and 2023. The study population was grouped into two. In the first group, 16 patients underwent VP shunt surgery using stereotactic optical navigation and also Strata (Medtronic, Minneapolis, USA) programmable valve in Liv Hospital, İstanbul. In the second group, 15 patients were operated using EM navigation and Codman Certas (Integra Lifesciences, New Jersey, USA) programmable valve in Florence Nightingale Hospital, İstanbul.

Result: The age range of patients was 36 to 87 years, with a mean age of (73.74±9.06). Twelve of the patients participating in the study were male, and 19 were female. All patients were operated because of normal-pressure hydrocephalus. In the EM navigation group, there

ÖZET

Amaç: Ventriküloperitoneal (VP) şant prosedürü, nöroşirürji alanında sıkça yapılan bir işlemdir ve normal basınçlı hidrosefali, enfeksiyon, travma veya subaraknoid kanama sonrası VP şant bağımlılığı gibi patolojileri tedavi etmek için kullanılır. Ventrikülü bypass eden bir şant kateterinin yerleştirilmesi kısa bir süre sonra şant disfonksiyonuna yol açacağı kesin olarak bilinmektedir. Bu nedenle, navigasyon destekli şant cerrahisi, serbest el kateter yerleştirmeye kıyasla kanülasyon denemelerinin sayısını azaltmada ve ventrikül kateterini uygun konumda yerleştirmede önem kazanır.

Gereç ve Yöntem: Bu retrospektif çalışmaya, 2016 ile 2023 yılları arasında elektromanyetik (EM) navigasyon ve optik navigasyon kullanılarak iki farklı cerrah tarafından iki farklı klinikte VP şant yerleştirilen 31 hasta dahil edildi.Çalışma toplumu iki gruba ayrınları iki gruba ayırıldı. İlk grupta, 16 hastada Liv Hastanesi, İstanbul merkezinde stereotaktik optik navigasyon ve ayrıca Strata (Medtronic, Minneapolis, ABD) programlanabilir valv kullanımı yapıldı. İkinci grupta, 15 hasta Florence Nightingale Hastanesi, Istanbul merkezinde EM ve Codman Certas (Integra Lifesciences, New Jersey, ABD) programlanabilir valv kullanılarak ameliyat edildi.

Bulgular: Hastaların yaş aralığı 36 ila 87 yıl arasındaydı, ortalama yaşları (73.74±9.06) idi. Çalışmaya katılan hastaların 12'si erkek, 19'u kadındı. Tüm hastalar normal basınçlı hidrosefali nedeniyle ameliyat edildi. EM grubunda, ameliyat sonrası bilgisayarlı tomografi (BT) bulgularına ve Hayhurst tarafından tanımlanan radyolojik ölçeğe göre 7 grad I ve 8 grad II hasta bulunmaktaydı; optik navigasyon grubunda ise, 13 grad I ve 3 grad II hasta

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were 7 grade I and 8 grade II patients, and in the optical navigation group, there were 13 grade I and 3 grade II patients according to the postoperative CT findings and the radiological scale defined by Hayhurst. In three patients from the EM Navigation group, subdural effusion developed due to overdrainage in different shunt settings. In none of these three patients an additional surgical intervention was needed. There were no intraparenchymal haemorrhage or shunt dysfunction complications in our study.

Conclusion: The use of navigation in shunt surgery prevents proximal failure and reduces the complications of intraparenchymal haemorrhage and shunt dysfunction. Although the use of optical navigation requires the use of a pinned headrest and an extended preoperative preparation time, the accuracy of ventricular catheter placement is similar when using optical navigation and EM navigation, despite these disadvantages. Due to its cost-effectiveness and high accuracy, the optically guided navigation system can be used in shunt surgery, especially considering the extra cost of the electromagnetic neuronavigation system.

Keywords: Electromagnetic navigation, optical navigation, shunt dysfunction

bulunmaktaydı. EM navigasyon grubundaki üç hastada, farklı şant ayarlarında aşırı drene olmaya bağlı subdural effüzyon gelişti. Bu üç hastanın hiçbirinde ek cerrahiye gerek duyulmadı. Çalışmamızda intraparankimal kanama ya da şant disfonksiyonu komplikasyonları izlenmedi.

Sonuç: Şant cerrahisinde navigasyonun kullanımı, proksimal başarısızlığı önler ve intraparenkimal kanama ve şant disfonksiyonu komplikasyonlarını azaltır. Optik navigasyonun kullanımı, çivili başlık ve uzatılmış preoperatif hazırlık süresi gerektirse de, ventriküler kateter yerleştirme doğruluğu, bu dezavantajlara rağmen optik navigasyon ve EM navigasyon kullanıldığında benzerdir. Maliyet etkinliği ve yüksek doğruluk açısından, özellikle EM sisteminin ek maliyeti düşünüldüğünde, şant cerrahisinde optik navigasyon sistemi kullanılabilir.

Anahtar Kelimeler: Elektromanyetik navigasyon, optik navigasyon, şant disfonksiyonu

INTRODUCTION

Ventriculopertioneal (VP) shunt procedure is frequently being performed in the field of neurosurgery to treat pathologies such as normal-pressure hydrocephalus, infection, trauma or VP shunt dependency after subarachnoid haemorrhage (1). Idiopathic normal pressure hydrocephalus (iNPH) is a condition in which patients present with symptoms of gait disturbance, urinary incontinence and dementia, and the ventricles enlarge without an increase in CSF (cerebrospinal fluid) pressure and also without any secondary diseases. Every year, 6 of 100,000 people are diagnosed with iNPH (2). In VP shunt surgeries, the importance of maintaining a brief operative duration and meticulous attention to sterility cannot be overstated, as they are critical factors in preventing postoperative infections. The literature reports a positive correlation between prolonged surgical duration and the incidence of infection (3, 4).

In the United Kingdom, over 3000 VP shunt surgeries are performed annually, whereas in the United States, the number exceeds 18,000 (5). Shunt dysfunction occurs in approximately 40% of these patients within the first year, predominantly due to proximal obstruction (6-8). Although the precise impact of ventricular catheter placement on shunt dysfunction remains not fully elucidated, it is well-established that a shunt catheter bypassing the ventricle will lead to shunt dysfunction shortly after placement (9). Therefore, navigation-assisted shunt surgery is significant in order to prevent infection, reducing the number of cannulation attempts compared to free-hand catheter placement, and also surgical duration and ensuring proper catheter placement (10-12). VP shunt placement may be performed utilising either the free-hand technique or with the assistance of navigation technology. The use of stereotactic optical navigation in the placement of VP shunts is a precise technique for catheter positioning. However, it comes with disadvantages such as the requirement for the patient to be positioned in a pinned headframe and an extended preoperative preparation time (13). In the past few years, frameless navigation systems have been frequently used in neurosurgery for biopsy and catheter placement procedures due to their low complication rates and minimally invasive approaches.

This study aimed to evaluate and compare the safety and efficacy of VP shunt insertion using EM (electromagnetic) navigation and stereotactic optical navigation.

MATERIAL AND METHODS

We retrospectively examined 31 patients who underwent VP shunt placement in two different clinics by two different surgeons using electromagnetic navigation and optical navigation between 2016 and 2023. The study population was grouped into two. In the first group, 16 patients underwent VP shunt surgery using stereotactic optical navigation and also Strata (Medtronic, Minneapolis, USA) programmable valve in Liv Hospital, İstanbul. In the second group, 15 patients were operated using EM navigation and Codman Certas (Integra Lifesciences, New Jersey, USA) programmable valve in Florence Nightingale Hospital, İstanbul. Informed consent forms were obtained from all patients. This retrospective study was conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study received ethical approval from the Ethics Committee of

Gaziosmanpasa Education and Research Hospital (Date: 03.07.2024, No: 16). The age range of patients was 36 to 87 years, with a mean age of (73.74±9.06). There were 12 male patients and 19 female patients. All patients underwent surgery because of normal-pressure hydrocephalus (Table 1, 2). Postoperative control Computerised tomog-

Table 1: Characteristics of patients in the electromagnetic navigation group.

Patient	Age/sex	Indication	Proximal catheter position (Grade)	Shunt valve type	Complication
1	83/F	NPH	I	Codman	None
2	83/F	NPH	I	Codman	None
3	68/M	NPH	II	Codman	None
4	79/M	NPH	I	Codman	Subdural effusion
5	71/F	NPH	II	Codman	Subdural effusion
6	75/M	NPH	II	Codman	None
7	65/M	NPH	II	Codman	None
8	68/M	NPH	II	Codman	None
9	66/F	NPH	I	Codman	Subdural effusion
10	79/M	NPH	I	Codman	None
11	79/F	NPH	II	Codman	None
12	71/F	NPH	II	Codman	None
13	79/F	NPH	II	Codman	None
14	74/M	NPH	I	Codman	None
15	71/M	NPH	I	Codman	None

NPH: Normal Pressure Hydrocephalus, F: Female, M: Male

Table 2: Characteristics of patients in the optical navigation group.

Patient	Age/sex	Indication	Proximal catheter position (Grade)	Shunt valve type	Complication
1	74/F	NPH + Parkinson	I	Strata	None
2	87/F	NPH	I	Strata	None
3	85/M	NPH	I	Strata	None
4	74/F	NPH	II	Strata	None
5	36/F	NPH	I	Strata	None
6	82/M	NPH	I	Strata	None
7	73/F	NPH	II	Strata	None
8	70/F	Parkinson + NPH	I	Strata	None
9	67/M	NPH	I	Strata	None
10	85/F	Operated NPH	I	Strata	None
11	68/F	NPH	I	Strata	None
12	78/F	NPH	I	Strata	None
13	76/M	NPH	I	Strata	None
14	74/F	Operated NPH	I	Strata	None
15	72/F	NPH	II	Strata	None
16	74/F	NPH	I	Strata	None

NPH: Normal Pressure Hydrocephalus, F: Female, M: Male. Grade I is defined as the placement of the ventricular catheter tip within the ventricle without touching the ventricle wall, grade II as the catheter tip touching the ventricular wall or choroid plexus, and grade III as the catheter tip being located outside the ventricle and within the parenchyma.

raphy (CT) images were obtained to assess postoperative bleeding and to verify the proper positioning of the ventricular catheter. The ventricular catheter position was confirmed with postoperative CT scan, and its accuracy was evaluated using the scale mentioned by Hayhurst (9). Grade I is defined as the placement of the ventricular catheter tip within the ventricle without touching the ventricle wall, grade II as the catheter tip touching the ventricular wall or choroid plexus, and grade III as the catheter tip being located outside the ventricle and within the parenchyma. There was no intraparenchymal haemorrhage or shunt dysfunction in the study.

Surgical technique

Electromagnetic navigation

After routine preoperative anaesthesia assessment and intubation, the patient was positioned supine and the Axiem mobile emitter of StealthStation S7 (Medtronic Surgical Technologies, Louisville, Colorado, USA) was placed on the operating room table (Figure 1A). The axiem tracker device was placed on the patient's head and stabilised with sterile drape. The anatomical landmarks on the patient's face were registered into the navigation software using a navigation probe, and the reliability of the system was verified using the navigation software. Routine preoperative sterilisation procedures were performed (Figure 1B). The scalp was incised in the frontal area consistent with Kocher's point. The subcutaneous tissue was dissected and the burr hole was created using an automatic perforator. Dura was coagulated and incised. A retroauricular curvilinear incision was made and continued with subgaleal dissection to create a pocket for the shunt valve. The shunt passer was passed from the abdominal incision to the retroauricular incision using the subcutaneous route. The peritoneal shunt catheter was moved inside the passer from the abdominal incision to the retroauricular incision. The ventricular catheter was guided to the preoperatively targeted point within the ventricle using Axiem navigation (Figure 1C). Peroperatively, the ventricular catheter was monitored in real-time with the assistance of the navigation software (Figure 1D). The target point for the ventricular catheter was the ipsilateral foramen of Monro. After puncture of the lateral ventricle, the catheter was passed from the frontal incision to the retroauricular incision using the subcutaneous route. Ventricular and peritoneal catheters were connected to the valve. Incisions were closed in an appropriate manner.

Optical navigation

Rigid cranial fixation was used with a 3-pin head clamp in all cases (Figure 2A). Preoperative data were trans-

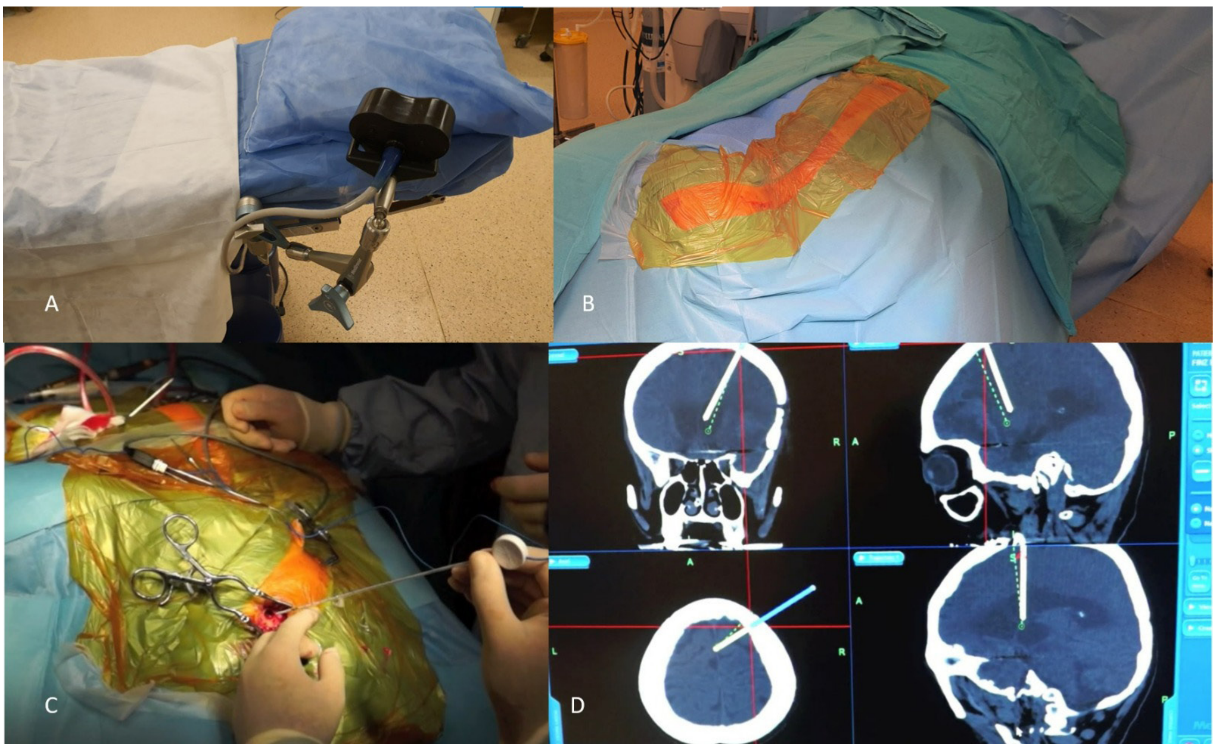

Figure 1: VP shunt insertion using EM navigation. A-B: Axiem mobile emitter of StealthStation S7 (Medtronic Surgical Technologies, Louisville, Colorado, USA) was placed on the operating room table, and the patient was positioned supine and routine sterilisation procedures were applied. C: View of the ventricular catheter with a sterile navigation stylet inserted and advanced towards the predetermined target within the ventricle. D: Peroperatively, the ventricular catheter was monitored in real-time with the assistance of the navigation software.

ferred to the navigation software, and the anatomical landmarks on the patient's face were registered into the navigation software using a navigation probe, and the reliability of the system was verified using the navigation software. After the routine sterile draping procedures, the patients were positioned supine (Figure 2C). Using the navigation software, the entry point was determined to be Kocher's point.

Instead of using a regular VP shunt insertion programme (Medtronic StealthStation S7 software), a neuronavigation-aided biopsy programme was used to increase target precision. The appropriate target (the right foramen of Monro) was marked as if it was a biopsy target. The burr hole was performed using automatic perforator, and the dura was coagulated and incised appropriately. The ipsilateral foramen of Monro was determined as the target point for the ventricular catheter. The navigation probe was inserted into the ventricle catheter and moved to the preoperatively selected target. Peroperatively, the ventricular catheter was monitored in real-time with the assistance of the navigation software (Figure 2C-2D). After the puncture of the lateral ventricle, the catheter was passed from the frontal area to the retroauricular area using the subcutaneous route. Ventricular and peritoneal catheters were connected to the shunt valve. Incisions were closed in an appropriate manner.

RESULTS

The age range of patients was 36 to 87 years, with a mean age of 73.74±9.06 years. There were 12 male and 19 female patients. All patients were operated on because of normal-pressure hydrocephalus (Table 1,2). Postoperative control CT images were obtained to assess postoperative bleeding and to verify the proper positioning of the ventricular catheter. The position of the ventricular catheter was identified by CT using the grading system mentioned by Hayhurst (9). In the EM navigation group, there were seven grad I and eight grad II patients, and in the optical navigation group, there were 13 grad I and three grad II patients according to the postoperative CT findings and the radiological scale defined by Hayhurst (9). In three patients from the EM Navigation group, subdural effusion developed due to overdrainage in different shunt settings. The preferred shunt valve Codman Certas (Integra Lifesciences, New

Figure 2: VP shunt insertion using optical navigation. A: Rigid cranial fixation was used with a 3-pin head clamp in all cases. B: The optical navigation system was placed on the operating room table and the patient was draped in a sterile fashion. C-D: The navigation probe was inserted into the ventricular catheter and moved to the preoperatively selected target, which was identified using navigation software. Peroperatively, the ventricular catheter was monitored in real time with the assistance of the navigation system software.

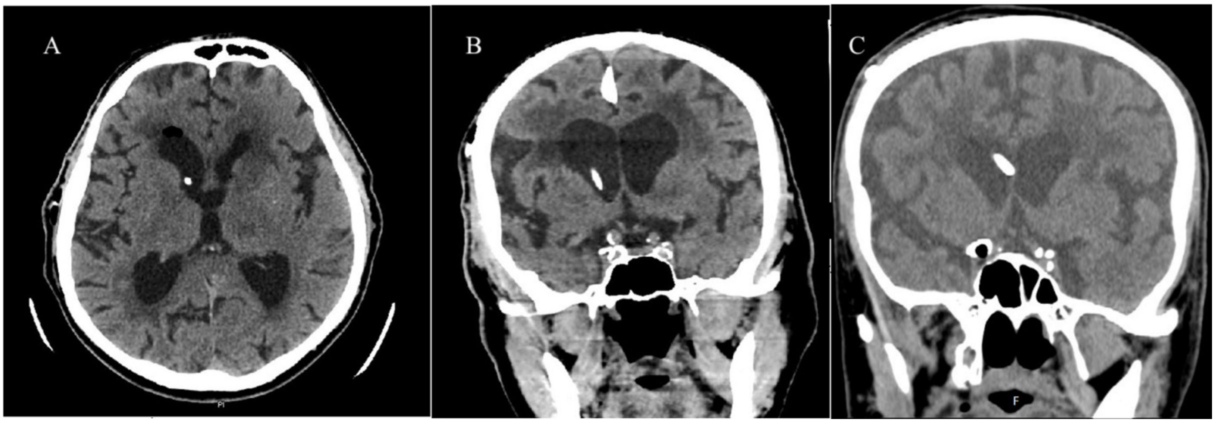

Figure 3: A: Grade I axial view non-contrast CT according to Hayhurst radiological grading, B: Grade I coronal CT scan without contrast, C: Grade II coronal CT scan without contrast

Jersey, USA) can be completely closed in this group. After the subdural effusion regressed in the control tomographies of the patients, the shunt valve was readjusted and gradually opened, and the patients' clinical symptoms improved significantly. In none of these three patients an additional surgical intervention was needed.

DISCUSSION

Due to the failures in ventricular catheter placement using the free-hand technique, the use of frameless navigation and optical navigation for ventricular catheter placement has been a subject of interest in neurosurgery, with studies aiming to assess their efficacy and safety compared to traditional techniques. The success rate of ventricular catheters placed using the free-hand technique in the literature varies between 8% and 65% (14). The failure in placing the ventricular catheter using the freehand technique is mostly referred to as proximal failure, which is the inability to place the proximal part of the catheter at the targeted point, resulting in its positioning in the parenchyma or on the ventricular wall (8, 15).

Azeem and Origitano shared their experiences with frameless navigation and the free-hand technique for ventricular catheter placement in the literature. They placed ventricular catheters using frameless navigation in 34 patients and compared the results with those of 38 patients in whom ventricular catheters were placed using the free-hand technique (16). They found that frameless navigation resulted in more accurate catheter placement, with a lower rate of proximal failures. In the study published by Hayhurst and colleagues, the free hand technique and EM navigation for ventricular catheter placement were compared, and it was found that the employment of neuronavigation significantly reduced the rates of revisions and complications (9). In our study, only 2 (6.25%) out of 32 patients were reoperated because of shunt dysfunction due to the placement of the shunt valve in the frontal area. These two patients were first operated at a different centre, so the shunt valve was placed in the frontal region instead of the retroauricular area. Shunt dysfunction may develop due to the inability to benefit from the effects of gravity because the shunt valve is placed in the frontal region instead of the retroauricular area.

VP shunts placed using EM navigation may not require fixation of the head, but their accuracy may be lower than that of shunts placed using stereotactic navigation (17-19). Although optical navigation systems have higher accuracy in comparison to EM navigation, they come with disadvantages such as the requirement for the patient to be positioned in a pinned headframe and an extended preoperative preparation time leading to infections (13). Furthermore, a visible line of sight is required between the tip of the navigation probe and the navigation camera system; otherwise, the tracking cannot be performed. Although optical stereotactic navigation has more accuracy than EM navigation and has extended preoperation time, there were no surgical infections and also no cases with malposition of the ventricular catheter in the EM and optical navigation groups in our study. In our study, we did not encounter any complications related to the use of the pinned headframe.

The correct placement of the ventricular catheter is important to minimise the risks of catheter dysfunction, intraparenchymal bleeding, and the need for repeated revision surgery (20). Navigation-assisted shunt surgery reduces the risk of catheter misplacement and risk of post operative parenchymal hemorrahage. In our study, postoperative CT scans showed that the position of all ventricle catheters were defined as Grade I or Grade II according to the CT scale mentioned by Hayhurst and there were no Grade III patients (9).

This proper positioning of ventricular catheters lead to favourable postoperative results, and there were no intraparenchymal haemorrhage or catheter dysfunction due to proximal failure in our study. In our study, all catheters were appropriately placed on the first attempt. This result contributed to the absence of complications such as intraparenchymal haemorrhage or infection. One of the most important complications in shunt surgery is the development of a subdural effusion or slit ventricle due to overdrainage or underdrainage of the shunt valve. Therefore, the use of adjustable shunts has become important to overcome these complications (2, 21, 22). In our study, we used a Codman adjustable valve in the group where electromagnetic navigation was used, and a Strata adjustable valve in the group where optical navigation was used due to the surgeon's preferences. Shunt valves were adjusted to appropriate pressure levels to prevent the development of subdural effusion or slit ventricle due to overdrainage, considering the ventricular sizes in the control CT imaging of the patients.

The EM module (Medtronic Surgical Technologies, Louisville, Colorado, USA) has an extra cost and is not always included to the standard neuronavigation system in every institution. This extra cost may be a significant issue, despite its advantage of requiring no frame and thus resulting in a shorter preoperative preparation time. With sufficient experience, the preoperative preparation time can also be reduced for optical navigation. Thus, our navigation-assisted shunt insertion may be applied without the need for an electromagnetic neuronavigation module. In our study, in three patients from the EM Navigation group, subdural effusion developed due to overdrainage in different shunt settings. The preferred shunt valve Codman Certas (Integra Lifesciences, New Jersey, USA) can be completely closed in this group. After the subdural effusion regressed in the control tomographies of the patients, the shunt valve was readjusted and gradually opened, and the patients' clinical symptoms improved significantly. In none of these 3 patients an additional surgical intervention was needed. Although the shunt adjustment in the optical navigation group (Medtronic, Minneapolis, USA) can be adjusted to provide the minimum drainage, it cannot be adjusted to completely stop the drainage. Therefore, using a shunt valve that can be adjusted to completely stop the drainage can be advantageous in this regard. In the stereotactic frame-based biopsy technique, although the preoperative preparation period may be longer compared with the frameless biopsy techniques, similar results have been obtained in terms of permanent morbidity, mortality, and permanent neurological deficit compared with the frameless biopsy methods (23, 24). In our study, when the control tomographies were evaluated according to the positions of the ventricular catheters, Grade I and Grade II results were found according to the Hayhurst radiological staging. Although we did not have Grade III patients according to the radiological classification, Grade II patients can be prevented with the addition of ultrasound support to navigation (25).

Some limitations of our study include a relatively small number of patients, the absence of a control group operated with the freehand technique, being a retrospective study, and a lack of statistical analysis. In the future, better results can be achieved with larger studies comparing the freehand technique, navigation technique, and ultrasound-guided ventriculoperitoneal shunt placement techniques. Combining navigation-guided shunt placement with ultrasound could indeed lead to even better results.

In VP shunt surgery, incorrect placement of the ventricular catheter can lead to intraparenchymal haemorrhage and shunt dysfunction due to proximal failure. The use of navigation in shunt surgery prevents proximal failure and reduces the complications of intraparenchymal haemorrhage and shunt dysfunction. Although the use of optical navigation requires the use of a pinned headrest and an extended preoperative preparation time, the accuracy of ventricular catheter placement is similar when using optical navigation and EM navigation, despite these disadvantages. Due to its cost-effectiveness and high accuracy, the optically guided navigation system can be used in shunt surgery, especially considering the extra cost of the electromagnetic neuronavigation system.

CONCLUSION

In VP shunt surgery, incorrect placement of the ventricular catheter can lead to intraparenchymal haemorrhage and shunt dysfunction due to proximal failure. The use of navigation in shunt surgery prevents proximal failure and reduces the complications of intraparenchymal haemorrhage and shunt dysfunction. Although the use of optical navigation requires the use of a pinned headrest and an extended preoperative preparation time, the accuracy of ventricular catheter placement is similar when using optical navigation and EM navigation, despite these disadvantages. Due to its cost-effectiveness and high accuracy, the optically guided navigation system can be used in shunt surgery, especially considering the extra cost of the electromagnetic neuronavigation system.

Ethics Committee Approval: The study has ethical approval from the Gaziosmanpasa Education and Research Hospital Ethics Committee (Date: 03.07.2024, No: 16).

Informed Consent: Informed consent forms were obtained from all patients.

Peer Review: Externally peer-reviewed

Author Contributions: Conception/Design of Study- U.Ö., M.O.A., T.K.; Data Acquisition – U.Ö., M.O.A., T.K.; Data Analysis/Interpretation- U.Ö., M.O.A., T.K.; Drafting Manuscript- U.Ö., M.O.A., T.K.; Critical Revision of Manuscript- U.Ö., M.O.A., T.K.; Final Approval and Accountability- U.Ö., M.O.A., T.K.; Supervision- U.Ö., M.O.A., T.K.

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