Real-time ultrasound-guided external ventricular drain placement: technical note

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In the United Kingdom, ultrasound-guided external ventricular drain (EVD) insertion is becoming the standard of care to mitigate the morbidity associated with catheter malposition and multiple passes. Many neurosurgeons routinely use ultrasound to check the preinsertion trajectory, although real-time visualization of ventricular cannulation is preferable since minor deviations can be significant in patients with smaller ventricles, and live visualization further enables the catheter tip to be adjusted away from the choroid plexus. Such real-time ultrasound navigation has traditionally been limited by technical factors including the challenge of simultaneously manipulating the probe and inserting the catheter within the same image plane.

The authors here describe a simple technique for precise EVD placement using a readily available bur hole ultrasound transducer attached to a 10-gauge needle guide channel (principally used for biopsy procedures) to accommodate a ventriculostomy catheter. The anticipated trajectory line is then projected onto the display and followed into the ipsilateral lateral ventricle. This is illustrated with a representative case and video demonstrating this rapid, user-friendly, and reliable technique. The authors invite others to consider this useful technique to minimize the risks of catheter misplacement or multiple cannulation attempts, which can be of particular benefit to junior neurosurgeons performing difficult cases under pressured conditions.

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EXTERNAL ventricular drain (EVD) placement for cerebrospinal fluid diversion is commonly performed for conditions such as acute hydrocephalus from any cause as well as to monitor and treat intracranial pressure. Although a basic procedure frequently delegated to junior neurosurgeons, catheter placement in a timely and accurate manner is critical as it is often performed as a life-saving procedure in an acute setting.

Insertion of an EVD is generally safe, though complications such as hemorrhage and suboptimal placement have been reported in up to 40% of cases.⁹ Huyette et al.⁵ performed a retrospective study of 90 patients and found that just 56% of EVD catheter tips were located within the ipsilateral lateral ventricle and 22% in the extraventricular spaces. Two passes were required per successful insertion overall, with results similar to those in other reported se-

ries.¹ Such findings have led several authors to conclude that current ventriculostomy practice leaves room for improvement and calls for wider adoption of image-guided insertion.^{1,5} The latest 2016 consensus statement guidelines on EVD insertion and management from the Neurocritical Care Society also recommend considering image guidance in cases of distorted ventricular anatomy or unusually small ventricles.⁴

Two current meta-analyses, comprising 2428 and 2829 cases, respectively,^{2,3} emphasized a wide range of estimated bleeding risk (from 0% to over 40%), attributable to varying definitions and study designs, with pooled overall rates of 7% and 8.4%. More recent data from the randomized controlled Clot Lysis: Evaluating Accelerated Resolution of Intraventricular Hemorrhage Phase III (CLEAR III) trial revealed a 16.8% hemorrhage rate, based on the

ABBREVIATIONS EVD = external ventricular drain; UK = United Kingdom; VP = ventriculoperitoneal.

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FIG. 1. Bur hole ultrasound transducer (10 × 8.6 mm) with a mounted 10-gauge guide channel, with illustrated trajectory line. Copyright BK Medical. Published with permission.

first 250 cases, with 2.4% of subjects deemed to have suffered clinically symptomatic bleeding.³ There is evidence that increasing the number of EVD placement attempts is a risk factor for this complication.⁶

In the United Kingdom (UK), EVD insertion is not routinely performed as a bedside procedure, but is performed in the operating theater unless the patient is in extremis. Intraoperative ultrasound has gained widespread acceptance as it permits real-time visualization of the lateral ventricle before and during catheter insertion. The anticipated trajectory line can be projected on the display and, when necessary, adjusted for optimal catheter positioning to avoid the choroid plexus or other potential obstructions such as an intraventricular hematoma. This image-guided approach minimizes the likelihood that multiple passes will be required to enter the ventricle, thus reducing the risk of hemorrhage and inadvertent injury to surrounding structures. In many institutions, including our own, it is standard practice to use a bur hole ultrasound probe to check the planned trajectory prior to catheter insertion. However, true real-time ultrasound guidance—that is, live visualization of the catheter entering the ventricle—is limited by technical factors, such as the size of the bur hole, and the difficulty of both manipulating the bur hole probe and inserting the catheter simultaneously within the same image plane.

Here we describe a technique of using a bur hole ultrasound transducer along with a readily available 10-gauge needle guide channel (typically used for biopsy procedures) to accommodate a ventricular catheter. In the literature, we identified one relevant paper (10 cases) from 2007 describing real-time ultrasound-guided insertion of ventriculoperitoneal (VP) shunt catheters in a pediatric cohort, all of which were positioned optimally on the first pass without complication,¹¹ but no such technical notes using contemporary imaging technology in adults. A report of 3 cases, which describes the use of ultrasound to customize EVD insertion points and trajectories to accommodate distorted and dynamic anatomy, also illustrates a potential application of the method we describe.⁷

We therefore present a simple technique utilizing readily commercially available equipment for precise ventricular catheter placement in adults (and adolescents). We have used this method with good results at our institution, and we illustrate the technique with a representative case and video.

Equipment and Methods

This technique requires a portable neurosurgical ultra-

sound scanner with bur hole transducer. At our institution, we use the Flex Focus 800 (BK Medical) with a 10 × 8.6-mm footplate bur hole transducer (Burr-Hole 8863) onto which is mounted a sterile single-use needle guide channel (UA1346). This apparatus is principally designed for biopsy needles but comes in a range of sizes from 20 to 10 gauge, which allows passage of the typical ventricular catheter used in an adult population (Fig. 1). We use the channel designed for a 10-gauge needle (outer diameter 3.404 mm), which easily accommodates the Codman Bactiseal catheter (3-mm outer diameter, Codman & Shurtleff Inc.) used at our institution. Codman also manufactures a larger Bactiseal ventricular catheter, which is, to our knowledge, the largest on the market, but with an outer diameter of 3.4 mm is still not greater than 10 gauge in size.

To accommodate the mounted ultrasound probe and catheter, at least a 13-mm-diameter bur hole is required (assuming a 10-mm footplate such as ours). If a standard 14-mm perforator drill is used, it will typically produce an 11-mm inner hole, which can then be enlarged to around 15 mm using Kerrison rongeurs or a cutting bur drill or via the use of 2 “spectacle” bur holes made with the perforator.

In an illustrative case, we performed an EVD insertion using a standard incision over Kocher’s point. After scraping back the periosteum, two 14-mm bur holes are placed horizontally side by side with overlap, with the more medial bur hole placed over the intended EVD insertion site (Fig. 2). An ultrasonic bur hole probe with the EVD holding attachment is placed over the lateral bur hole, the septum pellucidum and ipsilateral lateral ventricle are identified on ultrasound, and the exact entry point of the EVD is then determined. Next, a small cruciate durotomy is performed with pial diathermy and incision over the in-

FIG. 2. Two “spectacle” bur holes are placed over Kocher’s point to accommodate both the EVD catheter and the ultrasound transducer (US). L = left; R = right.

FIG. 3. Intraoperative coronal ultrasound images demonstrating the target ventricles. **A:** The lateral ventricles are identified by first locating the septum pellucidum, and the adjacent hypoechoic spaces are the lateral ventricles (*outlines with asterisks*). Note the hyperechoic choroid plexus at the level of the foramen of Monro. *Small dots* represent the anticipated trajectory projected on the monitor. **B:** The distance from the guide channel entrance to the first dot on the image puncture line is approximately 7 mm (0.3 inch) with the distance between dots being 5 mm (0.2 inch). The guide channel is angled at 8° to the transducer's image axis. **C:** Real-time tracking of the EVD following the *dotted line* as the drain is being inserted.

tended EVD insertion site, and the probe along with the EVD is secured within the attachment and is directed under real-time ultrasound guidance into the ventricle (Fig. 3 and Video 1).

VIDEO 1. Video clip demonstrating intraoperative ultrasound using a bur hole transducer for image-guided cannulation of the right lateral ventricle. Copyright James Manfield and Kenny Yu. Published with permission. [Click here to view.](#)

Once the catheter is in the correct position, it is tunneled and secured.

Discussion

External ventricular drain insertion can be performed either freehand using surface landmarks or with the aid of image guidance such as neuronavigation or ultrasound. Our traditional practice entails the use of an ultrasound probe to identify and confirm the catheter trajectory prior to freehand insertion. However, since the attempted ventriculostomy is not performed under direct visualization, there may be deviations from the intended trajectory, which can be particularly significant in patients with smaller ventricles. Furthermore, confirming the final position of the catheter following placement (by reintroducing the ultrasound probe) is often difficult because the catheter itself obscures the ultrasound waves. In comparison, the use of a fixed guide channel with the expected trajectory projected on the display image means that the depth of the tip is always clearly shown. In our experience, the simplicity of our technique makes it robustly error proof, which is a particular advantage for a procedure frequently performed by junior staff under pressured conditions, and especially useful for challenging cases in which ventricles are not enlarged or distorted.

Although intuitively apparent, there is no Class I evidence to date that image-guided catheter insertion leads to better clinical outcomes. However, a number of studies have evaluated image guidance in the context of both EVDs and ventricular shunt catheters, including a recent

well-designed retrospective analysis of 249 cases that identified the use of the freehand technique as the only risk factor for inaccurate placement.¹² The recent Neurocritical Care Society evidence-based consensus statement on EVD insertion and management now advises clinicians to consider image guidance for difficult cases (that is, those with small ventricles or distorted anatomy).⁴ Ultrasound has a clear advantage over stereotactic neuronavigation in terms of speed of setup and avoidance of the additional imaging sequences typically required for registration. For VP shunts, to which our technique is equally applicable, accurate positioning of the proximal catheter has been found to be among the most important variables predicting shunt longevity.¹⁰ Given the widespread availability of ultrasound machines, EVD insertion using ultrasonic guidance has become the expected standard of care in most UK institutions. With practice, the described technique adds only minimally to the operating time, which is more than recouped by those occasions in which multiple ventricular catheter passes may have otherwise been necessary. By enabling the surgeon to be confident of the catheter location, the procedure may also preclude the need to obtain a postoperative CT scan. The only potential drawback to this technique is the need to enlarge the bur hole slightly, which we do not believe adds any significant morbidity when weighed against the advantages. It is estimated that in the United States alone, approximately 500,000 EVDs were inserted between 1988 and 2010.⁸ Given such a case volume, it follows that even marginal refinements in technique are likely to translate into improved outcomes for a significant number of patients.

We recognize that in the United States most ventriculostomies are performed at the bedside in a critical care unit setting by using a twist drill bur hole and that the routine use of ultrasound would warrant a significant change to current practice, unlike in the UK where the above technique would be easily adopted. However, Phillips et al. have described a series of 3 challenging cases in the

FIG. 4. Proposed clinical algorithm for the management of patients with hydrocephalus requiring EVD insertion. Head CT scans are first reviewed to assess ventricular size and anatomy. In units where image-guided insertion is not part of the standard EVD insertion protocol, bedside cannulation is performed for patients with large ventricles and normal anatomy. For technically difficult cases with small ventricles and/or distorted anatomy, ultrasound (US)-guided insertion is advised. In addition, patients who have had multiple failed attempts at insertion should proceed to US-guided insertion in the operating room (OR).

United States in which ultrasound guidance was used for bedside EVD insertion in a critical care setting after a bur hole had been made using a handheld battery-powered drill with a 14-mm “perforator” drill bit and then enlarged with a side-by-side twist drill bur hole and/or a Kerrison rongeur, as we describe.⁷ Although we do not have experience with this approach, it does suggest the feasibility of applying our technique at the bedside, if the appropriate equipment is available, as well as in the operating room. We would, however, anticipate that in the United States setting this technique would be reserved for challenging

cases with difficult or distorted anatomy or in which there have been multiple unsuccessful ventricular catheter passes. We therefore suggest a putative treatment algorithm as seen in Fig. 4.

Conclusions

Traditional freehand EVD insertion is associated with suboptimal placement and hemorrhage in a significant number of cases. Given its ready availability, ultrasound guidance is increasingly becoming the standard of care in

many institutions including our own. We describe the use of a biopsy needle guide adapter, which, when mounted on a bur hole ultrasound transducer, facilitates the accurate real-time placement of ventricular catheters in a rapid, user-friendly, and reliable manner. We believe this useful technique minimizes the risk of complications related to catheter misplacement or multiple attempts at ventricular cannulation. It has minimal disadvantages and may be of particular benefit to junior neurosurgeons operating in pressured conditions or on challenging cases. Further efficacy studies are needed to assess the intuitively plausible hypothesis that image-guided ventricular catheter insertion leads to improved clinical outcomes.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: both authors. Acquisition of data: Yu. Analysis and interpretation of data: Manfield. Drafting the article: Manfield. Critically revising the article: Yu. Approved the final version of the manuscript on behalf of both authors: Manfield.

Supplemental Information

Videos

Video 1. <https://vimeo.com/232479342>.

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