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App-assisted external ventricular drain insertion

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The freehand technique for insertion of an external ventricular drain (EVD) is based on fixed anatomical landmarks and does not take individual variations into consideration. A patient-tailored approach based on augmented-reality techniques using devices such as smartphones can address this shortcoming.

The Sina neurosurgical assist (Sina) is an Android mobile device application (app) that was designed and developed to be used as a simple intraoperative neurosurgical planning aid. It overlaps the patient's images from previously performed CT or MRI studies on the image seen through the device camera. The device is held by an assistant who aligns the images and provides information about the relative position of the target and EVD to the surgeon who is performing EVD insertion. This app can be used to provide guidance and continuous monitoring during EVD placement.

The author describes the technique of Sina-assisted EVD insertion into the frontal horn of the lateral ventricle and reports on its clinical application in 5 cases as well as the results of ex vivo studies of ease of use and precision. The technique has potential for further development and use with other augmented-reality devices.

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KEY WORDS external ventricular drain; augmented reality; image-guided surgery; Android app; neuronavigation; diagnostic and operative techniques

Several techniques have been developed in the past to improve the accuracy of external ventricular drain (EVD) insertion. Jamshid Ghajar developed his guide to improve accuracy in 1985.[1] Neuronavigation has been applied to the insertion of EVDs and has increased the accuracy. However, due to the time and resources required for these techniques and the fact that the majority of EVD placements are done by postgraduate Year 1 and Year 2 medical officers in emergency situations,[2] these techniques are not commonly used.[4]

The freehand technique for EVD insertion is based on fixed anatomical landmarks and does not take individual variation into consideration. A patient-tailored approach based on the use of augmented-reality techniques can address this shortcoming.

Smartphones are popular and have potential for intraoperative use in association with augmented-reality mobile device applications (apps). Although there are available apps that could be used for EVD placement, the need for certain features and the potential for further applications by other devices like augmented-reality glasses (e.g., Google Glass) led to the development of a simple new app for intraoperative planning.

The Sina neurosurgical assist (Sina) is an Android app written in Java code and available for download from the Google Play Store. It was designed and developed to be used as a simple intraoperative neurosurgical planning aid.

This article describes the technique of Sina assistance for EVD insertion in the frontal horn of the lateral ventricle and reports on 2 small studies assessing ease of use of the app for an unscrubbed assistant and the effect of imprecise overlap on precision.

ABBREVIATIONS app = mobile device application; EVD = external ventricular drain; OR = operating room.

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App Instructions

Sina simply overlaps (superimposes) transparent images from radiological studies of the patient (CT/MRI) on the live feed from the device camera. (The app can also overlap radiographs, but CT or MR images are required for guiding EVD insertion.)

When the app is launched, the first page shows the instructions for use. A "Select Image" button is clicked to load the images from the image gallery of the Android device. After an image is selected it will show up on the device screen as transparent and overlaid on the live feed from the camera. Magnification cannot be modified through Sina. If the radiological image selected from the gallery is in an orientation different from the patient's position, the image can be "flipped" (changed to the mirror image of the original) by double tapping.

The app is designed to be used in portrait mode.

Intraoperative Technique

Prior to surgery, the appropriate axial and coronal CT/MRI slices are selected based on the planned location of the end of the EVD within the lateral ventricle, preferably at the level of the foramen of Monro. Photographs of these images are taken in portrait mode.

The appropriate length of the EVD catheter (length required to reach the target) is measured using the coronal and sagittal CT or MR images.

After administration of the appropriate anesthetic agent(s), if required, and positioning of the patient in a supine neutral position, Sina is launched and the previously obtained axial image is loaded from the image gallery and overlapped onto the live feed from the camera. The camera position is adjusted so that the coronal suture of the patient's head matches its location on the imported image. An incision is marked on the scalp 1 cm anterior to the coronal suture and close to the lateral edge of the lateral ventricle. Since the trajectory of the catheter insertion can be changed according to the coronal image using Sina, this step is optional, and different incision sites may be used as long as the expected trajectory line of the EVD stays in the selected coronal image plane and the expected length of the EVD catheter has been calculated accordingly.

The patient's head should be positioned, prepared, and draped so that the nose and eyes and the contour of the forehead can be seen through the drape (Fig. 1). In an operating room (OR) setting, turning the head to the opposite side makes exposure easier. The midline is marked on the drape with a marker that can be easily seen through the lens of the Android device. Any other landmarks, such as a skull dent or radiodense markers, that can be matched with their location on the coronal image can also be used.

The setup can be modified according to the surgeons' preferences and operating circumstances, as long as the midline and contour of the skull can be seen well on the Android device display without disturbing the rest of the team during the procedure.

Before scrubbing, the surgeon can load the coronal image on Sina and hand it over to an unscrubbed assistant. Alternatively, the image may be loaded by the assistant.

After preparation of the site and draping, the incision and bur hole are made and the dura is opened. The appropriate coronal image is loaded (or has already been loaded by the surgeon), and the unscrubbed assistant overlaps the coronal radiological image onto the real-time view of the patient's head. The surgeon can also put her or his finger on the skull (e.g., off the midline at the coronal plane of the bur hole) as a reference point for the contour of the skull to make overlapping of the previously loaded coronal image onto the live view of the patient's head easier for the assistant. The room lights may interfere with the ability to view the image on the device screen and may need to be temporarily adjusted. Before the actual EVD insertion, the surgeon can recheck to ensure that the midline of the patient's face and the contours of the skull coincide properly with the coronal radiological image. This is the key step. Improper overlapping of the image, particularly in patients with small ventricles, decreases the precision of the trajectory.

FIG. 1. An example of the setup for Sina-assisted EVD insertion, using a U-shaped drape and sticky transparent covering over the head. The patient's head should be positioned, prepared, and draped so that the nose and eyes and the contour of the forehead can be seen through the drape. Figure is available in color online only.

The principles of surgical technique are those of freehand technique. The trajectory line of the insertion should be in the selected coronal image plane and is guided by the assistant using Sina and continuously monitored during progression of the EVD placement. The ventricle should be encountered at the expected length of the EVD measured before the procedure. Filling the EVD with water and advancing the catheter slowly is helpful in patients with lower intracranial pressure or smaller ventricles.

Clinical Experience

The current version of the app was used for placement of an EVD in 5 patients aged 32 to 66 years. Two of these patients had subarachnoid hemorrhages and 3 had suffered head injuries. The width of the frontal horns was 3 mm or less in 3 of the patients. In all 5 patients, EVD placement was successfully achieved in the first pass, and postoperative CT confirmed the position of the tip of the EVD in the planned location. The procedures were performed in an OR.

Ease of Use and Precision Assessment

Ease of Use for an Unscrubbed Assistant

In practice, the unscrubbed assistants are often staff members who may not be familiar with the technique of EVD insertion or use of the app. The question of how easy it is for such an assistant to use the app and whether there is a learning curve for the assistant should be answered through a randomized trial with an appropriate number of users and inclusion of the assistant's experience with the app as a variable. However, to evaluate the feasibility of the use of Sina in practice and obtain some idea of the difficulty of using Sina by the potential assistants (other than the developer), the following qualitative test was arranged.

Testing

Two OR nurses, 2 operative assistants, and 1 registrar (orthopedic, not neurosurgical) were asked to participate in a test. They all were familiar with smartphones. They were asked to overlap the loaded coronal image onto a mannequin head and also rate the difficulty of the task. The participants were given a brief 3-minute introduction to EVD placement, Sina, and the test. Then the coronal image was loaded, and in the first run, the participants were asked to overlap the image onto the live camera image of a draped mannequin head, simulating the OR/ICU circumstances. The midline of the drape was marked with a marker pen (Fig. 2). In the second run, a single finger was placed on the vertex (off the midline in the coronal plane of potential bur hole), and the participants were asked to overlap the image so that the midline of the image overlapped the midline of the head and also that the contour of the image overlapped the contour of the skull, including the tip of the finger.

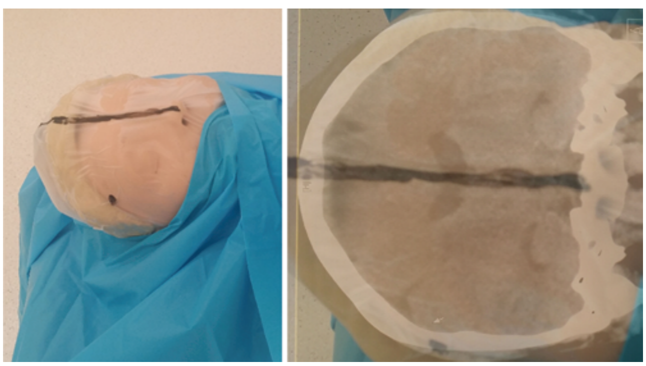

FIG. 2. Left: Draped mannequin head simulating the OR/ICU circumstances. The midline of the drape is marked as an aid in establishing accurate overlap of the images. **Right:** Screen shot from a Galaxy Note device during overlapping of the coronal image over the head of mannequin using Sina. Figure is available in color online only.

After the second run, the participants were asked how difficult they found the procedure and were instructed to rate the difficulty on a scale ranging from 1 to 10, with 10 representing the highest degree of difficulty.

Results

In the first run, all the participants could overlap the midline of the head and image satisfactorily; however 2 participants could not align the contours of the skull correctly—in both instances, the contours of the overlapped image were caudal to the corresponding contours in the live feed from the camera.

In the second run (with the finger on the vertex as a reference point), 4 out of 5 participants could overlap the image satisfactorily.

The participants were asked to rate the difficulty of the task after the second test. The average rating was 1.6 on a scale of 1–10 (range 1–2). Using the tip of the finger as a reference point made it easier for the participants. Overlapping the images took less than 2 minutes in both the first and the second tests for each of the participants.

Effect of Imprecise Overlap on Precision

Precise overlap of the coronal image with the frontal view of the patient's face is important, and Sina does not provide feedback as traditional neuronavigation systems do.

Testing

To estimate how much imprecise overlap affects precision and the importance of the relationship between the size of the patient's head and the size of the device screen, the app was tested on a glass ball vase using 3 smart devices with different sizes of screens (a Samsung Galaxy S2 phone with a 4.3-inch screen, a Samsung Galaxy Note 3 with a 5.7-inch screen, and a Samsung Tablet with a 10.1-inch screen). A point on the vase was marked as the target (simulating the target point in the ventricle). A photograph was taken so that the mark was visible on the photographic image. A thin wooden rod length was measured and marked so that it could hit the target on the vase (simulating the marking of the required length of EVD). The entry point of the vase was also marked so that the entry point remained the same for different tests. The vase, the photograph, the wooden rod, and the marked entry point represented, respectively, the head, the coronal radiological image of the head, the EVD, and the bur hole in real practice. For each of the 3 screen sizes, placement of the wooden rod was guided by Sina using the photograph, with 3 deliberate overlapping errors. A ruler was attached to the vase for measurements. A screen shot was taken each time the images were overlapped (Fig. 3). The overlapping errors (ratio) were estimated by averaging the deviation of alignment in 2 directions ([A + B]/2) divided by the height of the spherical part of the vase (D in Fig. 3). The targeting error (in millimeters) was estimated by calculating the deviation from the target (C) divided by the length of a 1-cm section of the ruler in pixels (CM) times 10 (10 C/CM). To reduce the error due to manual intervention, each measurement was performed twice and

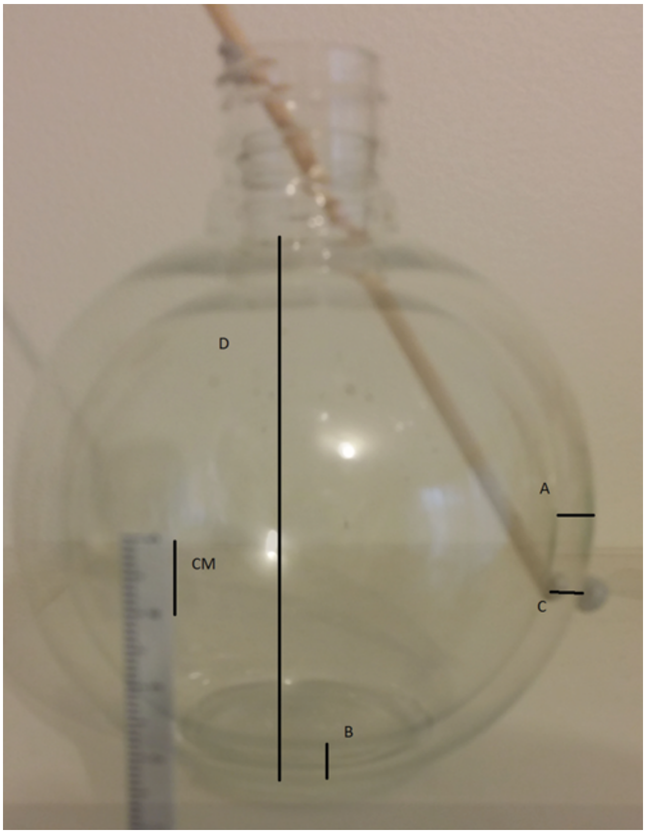

FIG. 3. Screen shot from the smart device after overlapping of the photograph (the smaller vase inside) over the vase (the bigger one outside) during the test described in the text. A "random" targeting error was made deliberately. The marked point on the vase represents the target point in the ventricle. The entry point of the vase was also marked so that the entry point remained the same for different tests. The vase, the photograph, the wooden rod, and the marked entry point represent, respectively, the head, the coronal image of the head, the EVD, and the bur hole in real practice. The overlapping error (ratio) was estimated by averaging the deviation of alignment in 2 directions ([A + B]/2) divided by the length of the ball part of the vase (D). The targeting error (in millimeters) is estimated as 10 C/CM. Figure is available in color online only.

the results were averaged. All initial measurements were made in pixels using Microsoft Paint (version 6.2).

The targeting errors (in millimeters) versus overlapping errors (ratio) were graphed, and the equation of the trend line was calculated (Fig. 4) using Calc computer software (LibreOffice 4.2.5.2).

Results

The graph in Fig. 4 shows that for almost every 2% increase in overlapping error (ratio of average deviation of alignment over the length of the coronal image of the head), we see a 1-mm increase in the estimated targeting error. The results also show that the larger the original photograph, the less the actual targeting error will be. In practice, larger images can be taken and loaded by smart devices with larger screens, so the size of the screen can indirectly influence the accuracy.

Mathematically and in physical reality, the relationship

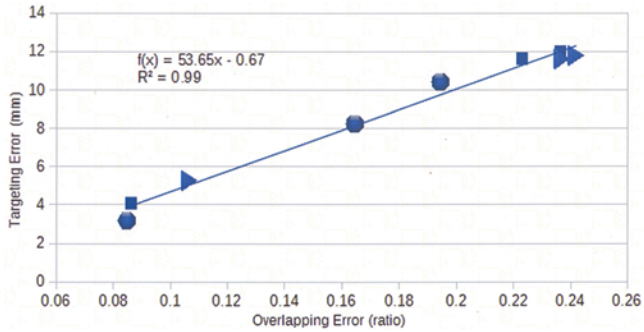

FIG. 4. Graph showing targeting errors versus overlapping (ratio) errors. The *triangles* represent results achieved with the Galaxy S2 (4.3-inch screen), the *circles* represent results achieved with the Galaxy Note 3 (5.7-inch screen), and the *squares* represent results achieved with the Samsung Tablet (10.1-inch screen). Figure is available in color online only.

between the targeting error and overlapping error is not linear, and the above-mentioned values are estimates for practical purposes.

Discussion

Using an app for EVD insertion is an example of the clinical application of augmented-reality techniques and potentially carries the discussed advantages of these techniques to improve the accuracy and outcome of a medical procedure.[3]

This paper describes the technique and shows the feasibility of using Sina to assist insertion of frontal EVDs. The above-described limited testing showed that in practice the imprecise overlap is one of the factors that could adversely affect the outcome; however, using markers or reference points on the drape and using larger images can improve the accuracy of the technique. Users do not require much training to be able to overlap the image and provide guidance.

Simplicity, availability of the device and software, and individual guidance can be considered as the potential advantages of the technique. On the other hand, manual image overlaying, lack of feedback about the precision of the overlap, the need for an assistant, and the need for rotation of the head in settings in which a frontal view of the face is not easily accessible can be disadvantages of the technique. The concept has significant potential for use and further development for smart and augmented-reality glasses. The true effectiveness of the current technique compared with the freehand method in various settings awaits evaluation through a randomized controlled trial. The trial should adjust for the experience of the surgeon, the assistant's familiarity with the EVD placement procedure, the assistant's experience with the app, the size of the ventricle, the setting (surgical suite or bedside), the duration of the surgery, the number of cases in which use of the app is abandoned, the number of passes, and the complications (including infection rate) as confounding variables.

Conclusions

The technique of EVD insertion with assistance of an

Android app has been described. The technique has potential for further development and application to other augmented-reality devices.

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Disclosures

The author is one of the developers of the product described in this paper, which is currently available for download from a third party (Google Play Store) free of charge. Sina has been developed by Amin Rakhsha, Shayan Eftekhar, and Behzad Eftekhar.

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