Patient-specific ventricular puncture trajectory plane and puncture trajectory: a novel method of frontal ventricular puncture

Chen-Yu Ding[1,2], Jun-Yu Lin[3], Yue Chen[1], Yue Pang[3], Xiao-Yong Chen[1], Wen-Hua Fang[1], Fang-Yu Wang[1], Yuang-Xiang Lin[1], De-Zhi Kang[1,2]

[1]Department of Neurosurgery, Neurosurgery Research Institute, The First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian 350001, China;
[2]Fujian Provincial Key Laboratory of Precision Medicine for Cancer, Fuzhou, Fujian 350001, China;
[3]Department of Thyroid and Breast Surgery, The First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian 350001, China.

Ventricular puncture is a common neurosurgical procedure, which is usually performed freehand using body surface anatomic landmarks as targeting references.[1,2] However, it is reported that the failure rate of freehand lateral ventricle puncture could be as high as 43% in traumatic brain injury cases if body surface anatomic landmarks are used as targeting references,[3] and the occurrence of hemorrhages associated with ventricular puncture could reach 16.2%.[4] Classic puncture sites, such as Kocher point, are helpful in improving the success rate of ventricular puncture. However, it is still risky to perform freehand puncture with classic puncture sites. Several causes could lead to this issue, including the following: (1) Individual patients have different conditions; a puncture approach suitable for all patients might not be possible. (2) Selection of puncture approach is largely dependent on the judgment of the surgeon, because the puncture approach does not usually fall on the coronal, sagittal, or axial images of the regular computed tomography (CT) scan; surgeons need to use spatial imagination based on CT images to design the ventricular puncture trajectory (VPT), which could lead to errors. (3) In freehand puncture, directional deviations could occur easily without the guidance of a frame as a fixed space reference to the puncture path.

Therefore, it is hypothesized that using the connection line of the bilateral external auditory canals as the axis, a set of images, which contains all the puncture trajectories aiming at this line, can be created by the CT multi-planar reconstruction (MPR) technology. Surgeons can customize the position of the VPT plane on this set of images and design VPT accordingly. For the actual application of the selected VPT in the actual surgery, a designed H-type guiding frame and a cell phone guiding cover are discussed in this article. To select the VPT plane, CT MPR technology was used to rotationally reconstruct images using the connection line between the bilateral external auditory canals as the axis of rotation [Figure 1].

For the actual application of the selected VPT in the actual surgery, an H-type guiding frame was fabricated, which locates the reality VPT plane via frame and secures the reality VPT via guiding groove [Supplementary Figure 1, http://links.lww.com/CM9/A721]. The specific steps of designing trajectory and obtaining parameters on the rotationally reconstructed CT images are shown in Supplementary Figure 1, http://links.lww.com/CM9/A721.

In addition, we also report a method that combines multiplanar CT image reconstruction with the use of an iPhone iOS app and a cell phone guiding cover [Supplementary Figure 2, http://links.lww.com/CM9/A722]. The iOS app (VirLaser Level, Version 2.6, kab70@rambler.ru, Russia) is used to locate the puncture direction of the ventricular catheter. This app can automatically measure the vertical angle of the iPhone (the number in green on the right side of the image) and the horizontal angle (the number on the bottom right corner). With this app, the location of the iPhone can be obtained and used to guide the puncture direction of the loaded ventricular catheter.

This study suggests a novel method of ventricular puncture. Using MPR, a set of CT images was rotationally reconstructed using the connection line between the bilateral external auditory canals as the rotation axis.

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.1097/CM9.0000000000001696

Chen-Yu Ding and Jun-Yu Lin contributed equally to this work.

Correspondence to: Dr. De-Zhi Kang, Department of Neurosurgery, The First Affiliated Hospital of Fujian Medical University, 20 Chazhong Road, Taijiang District, Fuzhou, Fujian 350001, China
E-Mail: kdz99999@sina.com

Chinese Medical Journal 2021;134(19)

Received: 09-06-2021 **Edited by:** Yuan-Yuan Ji

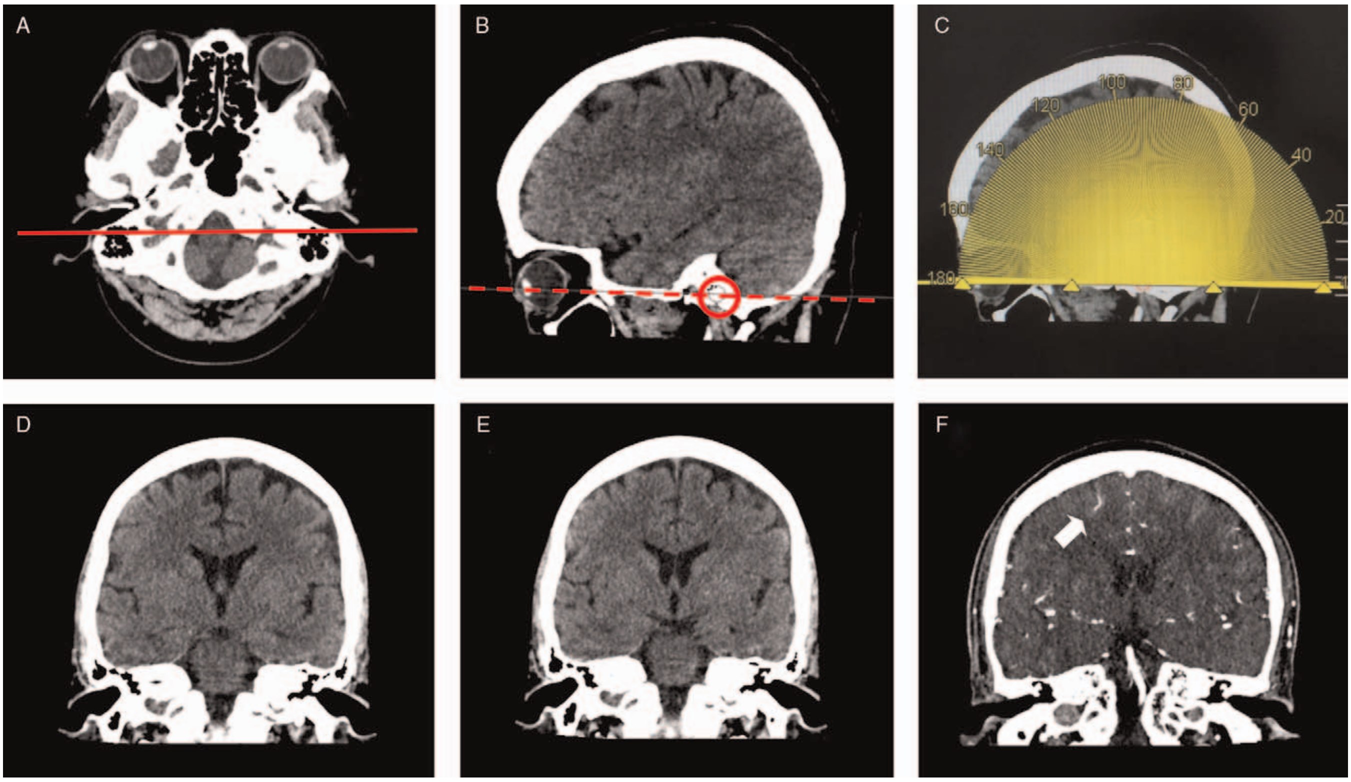

Figure 1: The VPT plane localization method. (A) The axial CT image containing the bilateral external auditory canals. The connection line of bilateral external auditory canals (red line) was selected as the rotation axis for the reconstruction. (B) The sagittal CT image containing the pupil. The connection line of the pupil and the external auditory canal (red circle) matches roughly with the orbitomeatal line (dotted red line) and was used as the reference plane. (C) CT images were reconstructed rotationally used MPR technology based on the original CT data. The position of the reconstructed CT plane is shown in yellow. A total of 180 images, 1° apart from each other, were obtained. This set of images was reconstructed using the connection line of bilateral external auditory canals as the rotation axis and included all VPT aiming at this line. This set of images can be used for selecting the VPT plane and designing the VPT. (D) In the 54th image of this set, the angle formed between this image and the reference plane was 53°, and bilateral external auditory canals and interventricular foramen can be identified on the image. The plane with interventricular foramen can be used for locating the anterior horn of the lateral ventricle. (E) In the 51st image of this set, the angle formed between this image and the reference plane was 50°; the interventricular foramen and connection line between bilateral external auditory canals was visible on the image. (F) A potential VPT plane reconstructed with CTA image for a male patient. When the right lateral ventricular foramen was used as the target to perform freehand puncture based on experience, blood vessel (arrow) could be damaged. The use of VPT plane for reconstruction might be helpful for individualized design of the VPT. CT: Computed tomography; MPR: Multi-planar reconstruction; VPT: Ventricular puncture trajectory.

Individualized VPT plane and VPT can be identified on this set of images. This novel method enables ventricular puncture with adequate pre-operative evaluation and theoretical high accuracy. Referring to the theoretical innovation of "implanting a curved lead to subthalamic nucleus and pedunculopontine nucleus,"[5] the core of this ventricular puncture method is to reconstruct the image plane that passes through the targets and contains the potential VPT.

Ventricular puncture is a routine neurosurgical procedure; however, compared to a patient with obviously dilated ventricles without deformation or location shift, the success rate of ventricular puncture of a patient with obviously deformed, dilated ventricle with location shift, refined ventricles, asymmetrically dilated ventricles, no ventricle dilation, or ventricle without obvious dilation will decrease significantly.[4] With the situations mentioned above, the best puncture point, direction, and penetration depth differ between different individuals. However, currently for ventricular puncture, pre-operative evaluation was usually performed using the axial, coronal, and sagittal CT images; no reconstruction was performed for the trajectory plane. Most of the time, the puncture trajectory does not fall into the regular sagittal, axial, or coronal CT images. When designing the VPT, neurosurgeons need to use spatial imagination on CT images, which could lead to vector errors. The actual ventricular puncture is usually performed blindly with the surface anatomic landmarks as reference for location, and is not individualized. The success rate of the surgery is closely related to the experience and skills of the surgeon, and errors such as deviation in puncture angle and over-penetrated catheter could occur. If the puncture fails for the first time, a repeated puncture could result in brain damage caused by the catheter, or even secondary intracranial hemorrhage.

Visualizing the puncture process is an effective way to decrease the failure rate of ventricular puncture. However, these methods, including real-time ultrasound, intra-operative navigation, and stereotactic frame, require a special set of equipment, which significantly increases the surgical time and limits the location where the surgery can be performed. Therefore, in this research, the original pre-operative CT images were reconstructed using the MPR method. The reconstructed set of images rotated around the connection line of bilateral external auditory canals and covered all puncture trajectories aiming at this line. Individualized VPT can be precisely located on this set of images, which is helpful for the full pre-operative patient assessment. Visualization of the puncture process is thus achieved with the pre-operative selections of puncture plane and puncture trajectory, and the use of guiding frame to locate the reality VPT plane and to secure the reality VPT intra-operatively. Reconstruction of this set of images can be performed by a radiologist based on the regular pre-operative CT image, requires no additional pre-operative planning or any special set of equipment during surgery, and has less impact on pre-operative preparation time.

Finally, the theoretical localization of VPT can be designed individually on the rotationally reconstructed CT images using the line connecting the bilateral external auditory canals as the rotation axis, and applied in surgery with the help of a customized guiding frame or a cell phone guiding cover. This novel method enables ventricular puncture with adequate pre-operative evaluation and theoretical high accuracy. A further clinical study is needed to verify whether it can be considered as a useful complement to the current ventricular puncture procedures.

Acknowledgements

The authors are grateful to Fei Jiang and Rui-Quan Chen for the CT reconstruction and to Xin-Zhi Zhang for the English editing of the manuscript.

Funding

This study was supported by a grant from the National Natural Science Foundation of China (No. 81901395).

Conflicts of interest

None.

References

1. Raabe C, Fichtner J, Beck J, Gralla J, Raabe A. Revisiting the rules for freehand ventriculostomy: a virtual reality analysis. J Neurosurg 2017;128:1–8. doi: 10.3171/2016.11.JNS161765.
2. Kim D, Son W, Park J. Guiding protractor for accurate freehand placement of ventricular catheter in ventriculoperitoneal shunting. Acta Neurochir (Wien) 2015;157:699–702. doi: 10.1007/s00701-015-2349-0.
3. AlAzri A, Mok K, Chankowsky J, Mullah M, Marcoux J. Placement accuracy of external ventricular drain when comparing freehand insertion to neuronavigation guidance in severe traumatic brain injury. Acta Neurochir (Wien) 2017;159:1399–1411. doi: 10.1007/s00701-017-3201-5.
4. Wilson TJ, Stetler WR Jr, Al-Holou WN, Sullivan SE. Comparison of the accuracy of ventricular catheter placement using freehand placement, ultrasonic guidance, and stereotactic neuronavigation. J Neurosurg 2013;119:66–70. doi: 10.3171/2012.11.JNS111384.
5. Ding CY, Yu LH, Lin YX, Chen F, Wang WX, Lin ZY, *et al*. A novel stereotaxic system for implanting a curved lead to two intracranial targets with high accuracy. J Neurosci Methods 2017;291:190–197. doi: 10.1016/j.jneumeth.2017.08.017.

How to cite this article: Ding CY, Lin JY, Chen Y, Pang Y, Chen XY, Fang WH, Wang FY, Lin YX, Kang DZ. Patient-specific ventricular puncture trajectory plane and puncture trajectory: a novel method of frontal ventricular puncture. Chin Med J 2021;134:2359–2361. doi: 10.1097/CM9.0000000000001696