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Midline Measuring Device Protocol

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Methods:

The Wishbone was then used to assist in the posterior burr hole localization procedure for patients undergoing VPS

The Wishbone secures to the patient's skull by way of 2 adjustable caliper arms that are reversibly placed into the left and right external auditory canals. Smooth spheres at the terminal ends of the caliper arms make firm, secure contact with the skull in this manner. Each caliper arm has a hinge-like attachment to a midline sighting housing to which a laser pointer is mounted. Symmetric sliding caliper alignment arms extend from the midline housing and connect to each caliper arm. The sliding caliper alignment arms ensure that the left and right caliper arms move symmetrically relative to the midline and maintain a congruent angular offset between the left and right caliper arms and the midline housing. The laser pointer attached to the midline housing dock is oriented such that the laser beam always bisects the angle between the 2 caliper arms and thus is equidistant from the 2 external auditory canal spheres When the Wishbone caliper arms are attached to the patient's left and right external auditory canals, the laser beam always illuminates a midline scalp point, even when the patient's hair is present.

Protocol:

1. Placement of the Wishbone

The Wishbone is designed specifically for use during posterior VPS surgery. After the induction of general anesthesia, the patient is positioned supine and sufficient hair is clipped to expose the right posterior scalp and midline. While the patient's head is positioned flat on the bed, the Wishbone caliper arms are adjusted, and the 2 external auditory canal spheres are firmly positioned within the left and right external auditory canals. Once the adjustment knob is tightened, the caliper arms are locked in position and the device is secured to the patient's skull. Initially, the device is rotated so that the laser beam is directed at the forehead just above the nose. If the laser beam illuminates the skin in the midline immediately above the nose, this indicates that the Wishbone has been appropriately secured to the skull. Next, an assistant flexes the patient's head and neck so that the surgeon can visualize the patient's posterior scalp. The device is rotated posteriorly so that the laser pointer illuminates the posterior midline. The surgeon uses a scalp marker to trace the posterior midline as delineated by the laser The assistant should hold the device still to ensure that the device does not slip out of the ears, especially in patients with a larger ear canal, while the surgeon is rotating the device posteriorly with the laser turned on and ensuring that the laser is moving in a straight line from the anterior to the posterior midline. This calibration process is demonstrated in the mandatory training session. A second line is manually traced parallel to the midline and 3 cm offset to the right. This second line delineates how far off of the midline the burr hole will be located. Different techniques can be used to plan the rostrocaudal location of the burr hole. One method involves measuring up from the external occipital protuberance (typically, 7 cm). Another involves using frontal scalp and external ear landmarks to

project a line posteriorly to determine the optimal posterior scalp rostro-caudal location. The burr hole location is determined by the intersection of the 3 cm paramedian line and rostrocaudal measurement. In anticipation that pen marks on the scalp may be washed away or poorly visualized following the initial prepping and draping, surgical staples are placed on the designated burr hole location and adjacent midline to insure visibility of these landmarks during the surgical procedure

2. Measurements

We recorded the time from initial placement of the Wishbone until the midline scalp was marked in patients undergoing VPS surgery. The location of the Wishbone-localized midline staple was identified on each patient's postoperative computed tomography (CT) scan, and the true anatomical midline was defined by drawing a line joining the most anterior with the most posterior point on the falx attachment at the level of the axial CT cut of interest on the reconstructed sequence. This method for defining the anatomical midline was used as it has been shown previously to have the highest interobserver agreement rate The distance from the Wishbone-determined midline scalp staple to the anatomical midline was defined as "distance from anatomical midline." The distance from the staple to the lateral edge of the sagittal sinus was defined as "distance from sinus." Finally, we measured the distance from the estimated center of the burr hole to the anatomical midline to generate a separate and complementary set of measurement data to study the Wishbone's localization accuracy. The distance was reported in positive values if the staple was to the patient's right of midline and negative values if it was to the left. The staples were removed on postoperative day 1 following the CT scan during the routine dressing change before discharge. If the staple was to the left of midline on the postoperative imaging studies, the distance measurement was assigned negative values.

Statistical Plan:

Statistical Analysis Data analysis was performed in R (3.5.1; R Foundation for Statistical Computing, Vienna, Austria) and GraphPad Prism 7 (GraphPad Software, San Diego, California, USA). Shapiro test was performed to test for normality. Mean, median, standard deviation (SD), and 95% confidence interval (CI) values were calculated and reported. Wilcoxon signed-rank test (nonparametric) was used to detect statistical difference with theoretical medians. $P < 0.05$ (2 tailed) was considered statistically significant