Reply:

G. Ringstad, K.E. Emblem, O. Geier, N. Alperin and P.K. Eide

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REPLY:

We thank Dr Bradley for the Commentary[1] on our article[2] entitled "Aqueductal Stroke Volume: Comparisons with Intracranial Pressure Scores in Idiopathic Normal Pressure Hydrocephalus."

The purpose behind using aqueductal stroke volume (ASV) as a predictor of shunt response in normal pressure hydrocephalus (NPH) should be providing additional value to already measurable sizes such as ventricular volume and thereby differentiating NPH from other types of dementia not expected to benefit from shunt surgery. Bradley[3] and Greitz[4] have proposed that the pathophysiology behind the increased ASV in NPH is due to compression of the ventricles by the increased inward expansion of the arterial pulse pressure. Indeed, increased intracranial pressure pulsatility is a strong indicator of reduced intracranial compliance,[5] which is thought to be a main underlying mechanism of NPH.[6] However, the physiologic explanation for a possible link between the magnitude of ASV and NPH has been called into question.[7] Our comparisons of ASV with intracranial pressure (ICP) and ICP amplitudes should, therefore, be highly relevant.

A noninvasive tool for selecting patients with NPH for surgery would certainly be preferable, provided that the method is not inferior to invasive methods in terms of overall patient outcome. The use of ASV for this purpose was proposed by Bradley et al,[8] when a beneficial shunt response was seen in 12/12 shunt responders with ASV above 42 μL. ASV was also measured in 24 additional patients who were not shunted, but the range and distribution of these measurements above/below the-42 μL threshold were not reported in the article. While some studies have supported the use of aqueductal flow rate for the diagnosis of NPH[9,10] and related flow rate to a possible shunt response,[11,12] few other studies have reproduced the beneficial utility of ASV in identifying patients likely to respond to surgical shunting,[13,14] and the diagnostic sensitivity and specificity of the method have never been assessed, to our knowledge. In contradistinction, several studies have not been able to demonstrate any association between a clinical improvement after shunting and increased ASV[15-17] or flow rate.[18] ASV has, however, been found to be elevated in several forms of dementia[19] and was strongly correlated with ventricular morphology.[20]

Our study incorporated a previously validated methodology for predicting shunt response by invasive ICP monitoring as well as measurements of ASV by phase-contrast MR imaging to allow direct comparison between 2 proposed predictors of shunt response. The shunt response rate in the study was 94%, indicating "true" NPH. The results indicate that ASV is related to ventricular size and aqueductal area, rather than reflecting the underlying pathophysiology of reduced intracranial compliance and increased pulsatile ICP or symptom severity. These results suggest that the ASV parameter should be used with care, even though ASV is measured noninvasively. In particular, the inability of a test to identify patients who should not undergo surgical shunting is problematic. The current treatment of NPH is brain surgery (shunt surgery), with a risk of severe complications such as cerebral bleeds and infection.[21-25] Deadly outcome of shunting may be anticipated in approximately 1/100 patients, whereas less serious problems related to shunting are observed in as many as one-third of shunted patients. In a previous report of shunting of 130 patients, a threshold of ICP wave amplitudes of >4 mm Hg on average and >5 mm Hg in >10% of recording time had a positive predictive value of 0.93 and negative predictive value of 0.91.[22] Thus, among patients with NPH with an ICP wave amplitude above the threshold, shunt response was seen in 9/10 patients, while it was seen in 1/10 patients with an ICP wave amplitude below the threshold.

We do not share Dr Bradley's view that all studies opposing the use of ASV have failed to demonstrate its beneficial use due to technical flaws. Although the image resolution of our method of 0.6×0.8 mm^2 has allowed partial volume averaging at the outer border of the aqueduct, the large aqueductal lumen area associated with hydrocephalus (in our study, the median area was 14 mm^2) should contain a sufficient number of voxels to derive reliable measurements. It is therefore unlikely that the pixel size used in this study has resulted in large errors that are on the order of the ASV magnitude. Moreover, the effect of any residual flow aliasing was further minimized by a standard aliasing postprocessing correction approach.

Which phase-contrast MR imaging (PCMR) is optimal is a matter of debate. In the now almost 20-year-old study from 1996,[8] still referred to as the main promoter study for the use of ASV in NPH,[1] the loss of a signal-to-noise ratio from high image resolution had to be (partially) compensated for by reducing the bandwidth and by using a half-Fourier algorithm. Still, the signal-to-noise ratio appeared to be substantial, and readers with special interest in the field are encouraged to retrospectively assess the original PCMR images presented in the article. Additionally, the compensations for loss of the signal-to-noise ratio resulted in a scan time of 14 minutes. From our experience, impairments due to motion artifacts may be a challenge when a 14-minute scan time is applied in patients with cognitive decline. In comparison with our study, the examinations may also have been affected by a lower magnetic field strength (1.5T versus 3T) and an inferior temporal resolution (18 frames per cardiac cycle versus 30–40).

Obviously, the ASV threshold level of 42 μL established from the 1996 study has been abandoned.[1] It is now stated in the Commentary[1] to our article that ASV can be measured on any MR imaging scanner in "10–20 elderly patients without enlarged ventricles," and by doubling this calibration value, one would identify shunt-responsive NPH. In our opinion, this approach seems somewhat arbitrary, and we await the scientific basis for this general recommendation.

Finally, we agree with Dr Bradley that methods for selecting patients with NPH to undergo surgical shunting vary by region and specialty. However, ASV measurements have never gained widespread acceptance. Because of the noninvasive nature of this tool, its use would certainly have been embraced by many if the evidence for its utility was convincing. It would have been most welcome and convenient to the neurologic community if the complex pathophysiology deciding the shunt response in NPH could be described by 1 single CSF flow parameter obtained from a few-minutes-long time interval. Our study, unfortunately, suggests this is not the case.

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G. Ringstad
Department of Radiology
K.E. Emblem
The Intervention Centre
O. Geier
The Intervention Centre
Oslo University Hospital–Rikshospitalet
Oslo, Norway
N. Alperin
University of Miami Miller School of Medicine
Miami, Florida
P.K. Eide
Department of Neurosurgery
Oslo University Hospital–Rikshospitalet
Oslo, Norway