Transcranial Duplex Sonography for Monitoring Hyperacute Intracerebral Hemorrhage

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Background and Purpose—Early hematoma growth is one of the main determinants of mortality in patients with intracranial hemorrhage (ICH). Transcranial duplex sonography (TDS) might represent a useful tool for the bedside monitoring of early ICH enlargement. We aimed to correlate ICH volumes measured by TDS and CT scan in patients with ICH evaluated <3 hours of symptom onset.

Methods—We prospectively studied 34 patients with supratentorial ICH evaluated <3 hours of onset. All patients underwent emergent CT scan and TDS examination on admission and at 6 hours. Major longitudinal, sagittal, and coronal hematoma diameters were measured on CT scan by a neuroradiologist and on TDS by a blinded operator with a time delay <30 minutes between both techniques. Total hematoma volume was determined using the formula for irregular volumes (longitudinal×sagittal×coronal)/2. Early hematoma growth was defined as an increase >20% in the hematoma volume at 6 hours.

Results—ICH was identified on TDS as an hyperechogenic mass located in the basal ganglia in 28 patients and in the lobar position in 6. Mean hematoma volume at baseline was 86±4 5 mL. At 6 hours, early hematoma growth was seen in 9 (26%) patients. An excellent correlation was found between TDS and CT measurements for all diameters: longitudinal (r=0.91, P<0.001), sagittal (r=0.85, P=0.002), coronal (r=0.79, P=0.022) and for total hematoma volume (r=0.82, P=0.001). When all obtained measures were matched, the intraclass correlation coefficient was 0.888 (95% CI, 0.8 to 0.937).

Conclusion—TDS showed an excellent correlation with CT in measuring the extent of bleeding in patients with hyperacute ICH. TDS may represent a reliable useful tool for monitoring ICH noninvasively at the patient’s bedside. (Stroke. 2009; 40:987-990.)

Key Words: growth ■ intracerebral hemorrhage ■ transcranial duplex sonography (TDS)

No proven treatment exists for patients with acute intracerebral hemorrhage (ICH), which leads to a high rate of mortality and morbidity.1 Several factors have been associated with poor clinical outcome in patients with ICH, including the initial ICH volume, a decreased level of consciousness, and hematoma enlargement.2–4 Substantial growth in ICH volume occurs mainly within the first hours after symptom onset and precedes neurological deterioration.5,6 Early detection of ICH growth may help to improve patient selection for emergent pharmacological or surgical treatment.

Transcranial duplex sonography (TDS) is a noninvasive technique that allows 2-dimensional imaging of brain parenchyma and visualization of acute ICH as a hyperechoic mass.7,8 This technique allows examining not only the extent of ICH, but also the presence of ventricular invasion and midline shift. Although CT9 and MRI10 have shown high accuracy in hyperacute ICH diagnosis, TDS has some potential advantages, including the concomitant assessment of brain hemodynamics and the feasibility to be performed at the patient’s bedside.11,12

The aim of this study was to correlate ICH volume and ICH enlargement measured by TDS and CT scan in patients with supratentorial ICH evaluated within the first 3 hours after symptom onset.

Subjects and Methods

Subjects
A total of 181 patients with ICH were admitted to the Stroke Unit of our hospital from May 2005 to March 2006. From them, we evaluated those who were admitted within the first 3 hours after onset (n=59).

These patients underwent a CT scan and TDS examination on admission and at 6 hours with a delay no longer than 30 minutes...
between both techniques. Volumes were measured on CT scan by a neuroradiologist and on TDS by an operator blinded to scan results.

We excluded those patients with a poor transtemporal window (n=6) or when the delay between TDS scan and CT was longer than 30 minutes (n=5). On 2 occasions, TDS was not operative. Four patients died before 6-hour CT could be performed, and baseline measures were ruled out.

Brain Imaging
Total hematoma volume on CT scan was estimated using the formula previously described for irregular volumes: $V = \frac{L \times S \times C}{2}$

Duplex sonography was performed transtemporally using a EUB-2000 Hitachi device with a phased-array 2-Mhz probe. The imaging of the brainstem was necessary first to obtain a landmark for orientation. By tilting the duplex probe, the maximum extent of the hematoma in the opposite hemisphere in both axial and coronal plans can be imaged and major longitudinal, sagittal, and coronal diameters obtained (Figure 1). To estimate ICH volume, we used the same formula previously described longitudinal $\times$ sagittal $\times$ coronal $/2$.11

Early hematoma growth with both CT and TDS was defined as an increase of $>20\%$ in ICH volume at 6 hours.

Statistical Analysis
Statistical analysis and comparisons were performed using the SPSS 13.0 statistical package. Measurements were shown as continuous variables expressed as mean±SD. Correlations between measurements were assessed by the Pearson’s correlation coefficient and Spearman’s when analyzing early hematoma growing. Agreement of values within techniques was assessed by the intraclass correlation coefficient and the Bland-Altman test. A probability value <0.05 was considered statistically significant.

Results
From 46 patients, ICH was not detected with TDS in 8 patients. Five showed a small-sized ICH on CT, and 3 had a difficult location for TDS (brainstem/cerebellum).

Finally, we evaluated 34 patients with ICH within the first 3 hours after stroke onset.

ICH was seen on TDS as a hyperechogenic mass located at the basal ganglia in 28 patients and lobar in 6. At 6 hours, early growth was observed in 9 patients (26%): 7 located at the basal ganglia and 2 were lobar.

Mean ICH diameters measured with CT scan were not significantly different as compared with those obtained with TDS. Mean basal volume was 41.06±39.39 mL on CT scan and 36.37±34.97 mL on TDS, and at 6 hours 46.15±43.21 mL on CT scan and 42.61±41.35 mL on TDS. When both techniques were compared, an excellent correlation was found regarding longitudinal diameter ($r=0.91$, $P<0.001$) and sagittal diameter ($r=0.85$, $P=0.002$). The correlation in coronal diameter was lower although quite good ($r=0.79$, $P=0.022$). Similarly, an excellent correlation was found regarding to ICH volumes ($r=0.82$, $P=0.001$) and to the detection of early growth of the hematoma ($r=0.78$, $P=0.03$; Figure 2A).

In our series, there was only one patient evaluated within the first 3 hours with mild ventricular involvement identified on both initial and follow-up TDS and CT scan. When all obtained measures were matched, the intraclass correlation coefficient was 0.888 (95% CI, 0.8 to 0.937; Figure 2A). Because SDs were large, we performed the Bland-Altman test, showing very good agreement between CD scan and TDS; the mean difference between both techniques measures was 0.5 (Figure 2B).

Discussion
Our results show that TDS is useful to identify the presence and extent of ICH <3 hours of stroke onset. Furthermore, early hematoma enlargement within the first hours can be monitored using TDS showing an excellent correlation with CT scan.

The accuracy of TDS is limited to the initial phase. From Day 1 to Day 5 after the onset of ICH, the hematoma is more echogenic than the surrounding brain tissue and it appears sharply demarcated, but later the margins become blurred and echogenicity starts to diminish.11 Although TDS is highly sensitive, it cannot reach the sensitivity of CT scan in the detection and follow-up of ICH. However, TDS represents a good option for monitoring patients, because it may avoid additional transfers and it is less stressful than other imaging procedures.

The advantage of this method is that patients with ICH can be examined on admission to the hospital and at the patient’s bedside with a simple, noninvasive, and time-saving method, mainly when CT is not immediately available.
Other complications of ICH, including ventricular involvement and space-occupying effects, can be reliably measured by TDS. One of these effects is the midline shift, allowing to identify a large ICH expansion and to predict a short-term outcome.\textsuperscript{14} Additional data in intracranial pressure may be obtained by analyzing the Doppler frequency spectrum of the basal cerebral arteries, giving information about follow-up and outcome.\textsuperscript{15} Although this study aimed to assess the usefulness of TDS in ICH enlargement during the acute phase, it could be useful to explore these factors in further studies.

As described previously, we found only one patient with mild ventricular involvement identified in both initial and follow-up TDS and CT scan. We detected another patient with intraventricular hemorrhage, but this patient died before follow-up CT scan, and these data were not included in the analysis. So, the small number precludes any valid correlation between both techniques regarding the presence and extent of intraventricular hemorrhage. The reason of this low rate of intraventricular hemorrhage detection in our sample may be in part due to the selection of those patients within the hyperacute phase (<3 hours).

Our study has some limitations such as the limitations of the technique. Like transcranial Doppler, TDS is operator-dependent, and the use of ultrasound performed by a trained and experienced sonographer will provide essential information for therapeutic and diagnostic consideration. Another limitation is that the size and location are decisive for correct visualization: small, very cortical (mainly parietopolar or frontal), and infratentorial bleedings may be missed in a significant number of patients, and approximately 15\% of the patients have no suitable acoustic bone window.\textsuperscript{11} For these reasons, 14 intracerebral hemorrhages were missed in our study. However, our aim was to assess the usefulness of TDS to monitor ICH, not its value to detect them.

Other study limitation is the small sample of ICH and the small number of ICH enlargements; however, the correlation and agreement between all measures (diameters, volumes, and volumes growing) were quite good (Figure 2) and therefore we can assume that TDS is a reliable technique to detect and to monitor ICH. However, based on our data, it cannot be assumed that TDS may replace totally CT in clinical decision-making, but it would help to select more
accurately those patients with possible complications to perform a CT scan. Further studies with larger numbers of patients with ICH during the acute phase are needed to confirm these results.

In conclusion, TDS showed very good correlation against CT scan in measuring the extent of bleeding in patients with ICH within the first 6 hours. TDS performed by a trained sonographer may represent a potentially useful method for monitoring early hematoma growth noninvasively at the patient’s bedside during the hyperacute phase.

Disclosures
None.

References
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