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Factors influencing intracranial vessel densities on unenhanced computed tomography: differences between hemispheres

Astrid E. Grams [a,*], Rafael Rehwald [b], Charlotte Schmittnägel [c], Thorsten Schmidt [d], Christian Tanislav [e], Martin Berghoff [e], Gabriele A. Krombach [f], Regina Moritz [f], Martin Obert [c], Elke R. Gizewski [a], Bernhard Glodny [b]

[a] Department of Neuroradiology, Medical University Innsbruck, Austria
[b] Department of Radiology, Medical University Innsbruck, Austria
[c] Department of Neuroradiology, University Hospital Gießen, Justus Liebig University, Germany
[d] Department of Diagnostic and Interventional Neuroradiology, Helios Wuppertal, University Witten-Herdecke, Germany
[e] Department of Neurology, University Hospital Gießen, Justus Liebig University, Germany
[f] Department of Radiology, University Hospital Gießen, Justus Liebig University, Germany

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ABSTRACT

The aim was to identify the factors influencing intracranial vessel density (VD). The Hounsfield units of the dense vessel and the contralateral side were measured in 34 patients with arterial clots, 20 with venous clots, and 196 without clots and correlated with skull thickness, density and dimensions, gender, age, red blood cell count (RBC), hemoglobin (HB), hematocrit (HT), creatinine, and sodium. Positive correlations were found between VD and HT, RBC, HB, creatinine, and occipital bone density. Density differences between the right and left intracranial vessels were more accurate (sensitivity/specificity/accuracy=0.91/0.93/0.93 and 0.75/0.87/0.85, respectively) for detecting clots than VD alone. HT, RBC, and HB are the main factors that correlate with VD.

1. Introduction

Hyperdense intracranial blood vessels seen in unenhanced computed tomography (CT) of the brain may be a sign of arterial or venous occlusion. Clotted blood appears hyperdense, as a local increase of hematocrit occurs during the clotting process [1,2]. Arterial clotting can be seen as the "hyperdense artery sign", indicative of early infarction, and an important tool for estimating the size of an infarction and prognosis [3,4]. In patients with clinical symptoms suspicious for an acute arterial or venous occlusion such as hemiparesis, aphasia, an altered state of consciousness, or headaches, it is necessary to differentiate immediately between occlusion and other causes of vessel hyperdensity. An elevated hematocrit due to dehydration, for example, has been suspected as a major cause of increased vessel density (VD) [5,6]. Other possible reasons for hyperdensity in or adjacent to vessels are calcifications, beam-hardening artifacts [7], and Hounsfield unit variations. [8] Factors influencing the density of intracranial blood vessels should affect both hemispheres equally; density differences between occluded and perfused vessels should be more accurate for the detection of clots than absolute vessel densities regardless of the CT scanner or technique used. The aims of the present study were to investigate potential factors influencing intracranial vessel densities and to test whether density differences between perfused and occluded vessels are more reliable for the diagnosis of vessel occlusion than measurement of absolute VD alone.

2. Material and methods

The local institutional ethics review board approved this retrospective study. Unenhanced cranial CT scans of 196 patients (75 female, 121 male; 19 to 92 years of age, mean age 55.1±18.5 years) without intracranial hemorrhage and without history of or suspected stroke were included, as well as unenhanced CT scans of 34 patients (9 female, 25 male; range: 8 to 90 years, mean age 63.4±8 years) with arterial clots (12 basilar arteries and 22 middle cerebral arteries) and 20 patients (11 female, 9 male; range: 16 to 90 years, mean age 51±23.1 years) with venous clots [10 superior sagittal sinus (SSS) and 19 sigmoid sinus (SSig)] were investigated (Table 1). The patients with intracranial clots were identified retrospectively using the radiology information system of our institution. Only patients with clots later confirmed by Computed tomography angiography (CTA), Magnetic resonance angiography (MRA), or conventional angiography were included. Imaging

* Corresponding author. Department of Neuroradiology, Medical University Innsbruck, Anichstraße 35, 6020 Innsbruck, Austria. Tel.: +43-512-504-27095; fax: +43-512-504-27096.
E-mail address: astrid.grams@gmail.com (A.E. Grams).

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Table 1
Clinical symptoms of the patients (f = female, m = male)

Clinical data		
Unenhanced CT scan in 176 patients without history of or suspected stroke	75 f. 121 m	Headaches or dizziness
Unenhanced CT scan in 54 patients with arterial or venous clots	Arterial: 9f, 25 m	
	12 BA	2 focal neurological deficit 4 somnolent 1 soporous 5 comatose
	22 MCA	22 hemiparesis or hemiplegia of the contralateral side 6 with left, 2 with right sided occlusion: additional aphasia, 3 impaired consciousness
	Venous: 11f, 9 m	
	10 SSS	4 headache 6 additionally nausea 1 focal neurological deficit 2 seizure
	10 SSig	In 6 comatose patients, the sinus thrombosis was associated with a traumatic brain injury, in 1 not.

Table 2
CT scanners used in patients with occluded vessels

	Windowing			
Manufacturer/Model	No.	Level (HU)	Width (HU)	Slice thickness (mm)
Siemens				
Somatom Definition Flash	27	35	96	4
Sensation 16	13	35	96	4
Somatom Definition AS+	1	40	100	4
Sensation Cardiac 64	2	30	76	4
General Electric				
Discovery CT750 HD	5	45	90	5
LightSpeed 16	3	35	85	5
Optima CT660	1	44	112	3
LightSpeed VCT	1	45	90	5
Philipps				
Mx8000	1	35	80	5

Number of patients (No.), window settings (HU) and slice thickness (mm) are indicated.

data were acquired using nine different CT scanners (Table 2) with a fixed tube voltage of 120 kV. The other acquisition and reconstruction parameters were variable. As some of the data sets were acquired in external hospitals and some of the CT scanners used have already been replaced by newer ones, only the window and the slice thickness documented were available for this retrospective evaluation. Scanners were from three different vendors: Siemens (Siemens Healthcare, Erlangen, Germany), General Electric (GE Healthcare, Chalfont St Giles, Buckinghamshire, UK) and Philips (Philips Healthcare, Best, The Netherlands). Region of interest (ROI) measurements were performed by consensus of two experienced board-certified radiologists. After magnification, ROI mean density and standard deviation (SD) measurements were performed in defined anatomical locations of the intracranial vessels adapted to the vessel size—the proximal M1 part of the middle cerebral artery (MCA), the distal part of the basilar artery (BA), the proximal part of the SSig, and the SSS proximal to the confluence of sinuses—in each patient of both cohorts (Fig. 1). Data from patients with and without clots were correlated with different morphometric and laboratory parameters (Table 3).

Table 3
Investigated factors influencing VD

Category	Influencing factor
Demographics	Gender
	Age (years)
Craniometry	Skull thickness frontal (mm)
	Skull thickness parietal (mm)
	Skull dimension anterior–posterior (mm)
	Skull dimension left–right (mm)
	Skull density frontal (HU)
	Skull density occipital (HU)
Laboratory	Erythrocytes (tera/l)
	Hemoglobin (g/l)
	Hematocrit (%)
	Leukocytes (giga/l)
	Creatinine (mg/dl)
	Potassium (mmol/l)
	Sodium (mmol/l)

Descriptive statistics (mean, median, SD, and minimum and maximum values) were calculated with Excel (Microsoft Office 2013, Microsoft Corp., Redmond, WA, USA) and SPSS Statistics (SPSS 23, IBM Corp., Armonk, NY, USA) software. Statistical evaluation was performed with GraphPad PRISM (PRISM 6, GraphPad Software Inc., La Jolla, CA, USA) and SPSS Statistics. Mann–Whitney *U* tests or Kruskal–Wallis tests were used for group comparisons, and the method of Spearman was applied for the evaluation of correlations. In addition, receiver operator characteristic (ROC) analyses were undertaken, and Youden indices were calculated [9]. Sensitivity and specificity were determined. Accuracy was calculated as the sum of the true positive and true negative tests divided by the sum of the true positive, false positive, true negative, and false negative tests. A *P*-value of 0.05 or less was considered statistically significant.

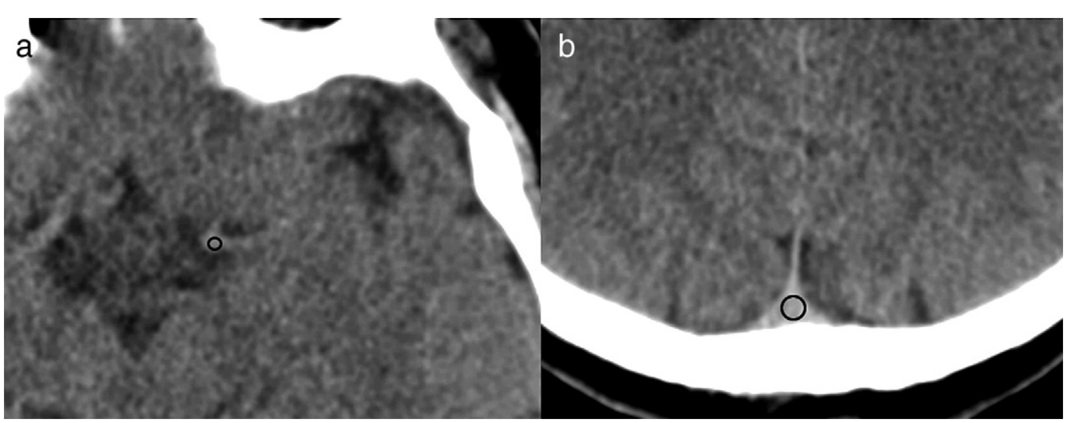

Fig. 1. ROI density measurements: Measurement examples in the left MCA (a) and in the SSS (b).