Arachnoid granulations are normal variants that protrude into the cerebral venous sinus lumen and produce focal defects in cerebral venography, contrast enhanced CT, and MRI. It should be differentiated from other lesions within the dural sinus lumen that produce focal defects. In the present study, we investigated the frequency and positional distribution of arachnoid granulations with multi-detector row CT. Simple post processing procedures on thin slice multi-detector row CT were performed. We found arachnoid granulations in nearly half of our participants. We observed that presence of arachnoid granulations showed no tendency in two sexes. No relationship between age and multiplicity, and an inverse relationship between age and the variants’ size existed. We concluded that as imaging technology continues to develop, the frequency with which normal variants are identified will also increase. Arachnoid granulations are a normal variant that all radiologists should be aware of and which should not be mistaken for pathological intra-sinus lesions. The relationship between characteristics of the variant (presence, number, size) and of the human subjects (gender, age) should be reviewed with larger samples.

Keywords: arachnoid granulation, dural sinus, MDCT, CT-venography

Introduction
Due to the increasing availability of high resolution imaging techniques it has become extremely important to recognize normal variations that mimic pathologies. Arachnoid granulations (AGs) are normal variants that protrude into the cerebral venous sinus lumen and produce focal defects in cerebral venography, contrast enhanced CT, and MRI (9). In particular, AGs should be differentiated from cerebral venous thromboses, which cause serious neurologic disorder. The frequency and apperance of AGs have been investigated with contrast enhanced CT, conventional venography, MRI and MR venography (5, 7, 9, 11, 12, 15, 16). As their frequency in multi-detector row CT (MDCT) -angiography or -venography has not been reported, we investigated their frequency and positional distribution in the primary sinuses. In the present study, we performed simple post processing procedures on thin slice MDCT to examine details of the primary sinuses.

Materials and Methods
The study included 154 consecutive patients that underwent CT-angiography or CT-venography between August 2007 and May 2008. Headache, subarachnoid hemorrhage, stroke, and suspicion of dural sinus thrombosis were the main reasons for the imaging in the present study.

The exclusion criterias were defined as CT-angiographies or CT-venographies determined as technically suboptimal (improper visualization of the primary dural sinuses) and such with appearance of dural sinus thrombosis. In all, 8 patients with dural sinus thrombosis and 6 patients that underwent technically suboptimal CT angiography were excluded from the study.

In all, the records of the 140 patients (72 female, 68 male; mean age: 47.5 ± 17.7 years; range: 4-92 years) were retrospectively reviewed for the presence of AGs by two radiologist (A.B., H.A.). Criteria for diagnosis of AG were determined as well-defined filling defect with round or oval shape with uni- or multilobulated contours. The distribution, number and size were noted. Any relationship between presence, size, number (multiplicity) of AGs and gender and age of the patients were investigated.

CT angiography and CT venography were performed with a commercially available Philips Brilliance CT scanner (Philips Medical Systems, Cleveland, Ohio), with a 64-row detector ring, minimum section thickness of 0.9 mm and pitch of 0.92. We administered 75 ml of non-ionic contrast medium (iodine, 300 mg/ml) at the rate of 4 ml/sec and used a 5–6-second or 45-second prescanning delay according to the particular aim of each investigation, such as determining arterial or venous pathology. The quantity of contrast material was recalculated according to body weight for pediatric cases. Evaluations were performed using a Philips Extended Brilliance Workspace work station (Philips Medical Systems, Best, Netherlands). First, two-dimensional (2D) multiplanar reconstructions (MPR) images were used to visualize the primary dural venous sinuses, with adequate window level and width. Next, 2D maximum intensity projection (MIP) series were created and saved. These first two steps took approximately 4–5 min. and were sufficient for investigation of the dural sinuses. When necessary, in particular for AGs located at the corner of the sinuses, in order to observe all of the borders, and the relationship with the cortical veins, other postprocessing
techniques including curved MPR and rotation center MPR, were used (Fig. 1). Rotation centres enable stabilization of a point or a lesion when obtaining oblique images. We did not use any optional reformation techniques, such as volume rendering display algorithms, which typically require more time.

Statistical analysis was performed for further evaluation of the findings. Chi-square test, independent-samples T-test, and Pearson correlation test were used for deciding about significance.

Results and Discussion

According to definition criteria of AG we determined that of the 140 participants, 66 (47.1%) had at least 1 AG of which 27 participants had single granulation and 39 had multiple (ranging between 2 and 6) granulations. In total, 148 AGs were observed.

All AGs appeared as well-defined, round- or oval-shaped filling defects in the sinuses. AGs’ size ranged between 2.7 and 18 mm (mean: 5.35 mm). Of the 148 AGs, 104 were smaller than 5 mm, 40 were 5-10 mm, and 4 were larger than 10 mm.

Veins draining into a cerebral venous sinus were found adjacent to all AGs (100%). We also found a tiny eccentrically located internal vein as a continuation of that adjacent vein, but could perceive it only in the AGs that were 4 mm and larger (43.9%) (Fig. 1).
The distribution of the patients (with and without AG) according to the imaging reasons

<table>
<thead>
<tr>
<th>Imaging reason</th>
<th>AG (-)</th>
<th>Rate (%)</th>
<th>AG (+)</th>
<th>Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarachnoid and/or intraparenchymal hemorrhage</td>
<td>24</td>
<td>60.0</td>
<td>16</td>
<td>40.0</td>
</tr>
<tr>
<td>Headache</td>
<td>16</td>
<td>45.7</td>
<td>19</td>
<td>54.3</td>
</tr>
<tr>
<td>Cerebrovascular attack</td>
<td>15</td>
<td>55.6</td>
<td>12</td>
<td>44.4</td>
</tr>
<tr>
<td>Mass (pre-operative vascular evaluation)</td>
<td>10</td>
<td>58.8</td>
<td>7</td>
<td>41.2</td>
</tr>
<tr>
<td>Suspicious of sinus thrombosis</td>
<td>6</td>
<td>60.0</td>
<td>4</td>
<td>40.0</td>
</tr>
<tr>
<td>Vertigo</td>
<td>6</td>
<td>54.5</td>
<td>5</td>
<td>45.5</td>
</tr>
</tbody>
</table>

collateral veins, dural enhancement, and brain swelling, or a history of associated disease (16). Extra-axial hemangiomas and meningiomas show marked contrast enhancement, unlike AGs (9, 14). Polypoid tumors and cavernous nodules contain denser fibrous tissues than do AGs (2, 3, 9), which demonstrate different density and signal intensity in CT and MRI, respectively. Another critical feature of AGs is their size. Although there is no consensus in the literature, Kan et al. (8) referred to AGs as “giant” when they are of sufficient size to fill the lumen of a dural sinus and cause local dilation or filling defects. Flow disturbance due to large AGs cause symptoms related to venous hypertension (1). In the present study we observed 4 AGs with size between 11 and 18 mm in 4 of 66 participants that had at least 1 AG: only the patient with the largest AG presented with headache. To prove the diagnosis of venous hypertension related with AG, measurement of intrasinus pressure at the proximal and distal parts of the sinus, and the pressure gradient across the AG are necessary. It is important to note that no invasive procedure was performed on our patient with the 18-mm AG due to the patient’s preference.

The technique used by us is the result of the development of more detector rows and sub-millimeter image thicknesses in CT technology, which combined with the use of different MDCT post-processing techniques, results in more frequent identification of normal variants.

The incidence of AGs has been investigated using different imaging modalities since 1996, including contrast enhanced CT, conventional venography, MRI and MR venography (5, 7, 9, 11, 12, 15, 16). Roche and Warner (15) reported AG occurrence rates of 0.3% for 3100 CT studies and 1% for 200 MRI studies. According to a study by Leach et al (11), AGs were observed in 24% of contrast enhanced CT examinations and in 13% of routine contrast enhanced MRI studies. Among studies in which MRI was the only imaging technique used, wide variations in the frequency of AGs are reported. Although Ikushima et al. (7) investigated all dural sinuses; they observed AGs in only 10% of their patients. Koshikawa et al. (9) investigated only the transverse sinuses and reported an AG frequency rate of 70.9%, which is similar to the 60.6% reported in a cadaver study (11). Slice thickness is probably the primary reason for the difference between Ikushima et al.’s (6 mm) and Koshikawa et al.’s (0.8 mm) results. Another possible reason for the differences in their results is that contrast enhanced T1-weighted spin echo images sometimes suffer from a non-uniform signal from the sinus and flow ghost artifacts.

We investigated all the primary dural sinuses and observed AGs in 47.1% of the patients. In a study of Koshikawa et al. (9) all the patients had symptoms, including tinnitus, dizziness, hearing loss, etc., which might have been related to posterior fossa pathology. The patients included in the present study were not selected according to any particular symptom as mentioned above. Therefore, our results may be more objective than those of Koshikawa et al. (9). However, Liang et al. (12) investigated the prevalence of normal dural structures including not only AGs but also intra-sinus septa and observed filling defects in 90 of 100 participants.

According to previous reports, AGs are thought to increase in number and conspicuity with age (6, 7, 10, 17). In the present study, however, we did not observe any significant correlations between age and the number of AGs. Koshikawa et al. (9) also reported no significant correlations between age and number of AGs, or between age and size of AGs. But, interestingly, in the present study an inverse relationship between age and size of the AGs was observed; to the best of our knowledge, to date there are no other similar reports. As such, more studies with larger samples are necessary in order to reach a definitive conclusion concerning this finding.

Although Roche et al. showed that AGs are usually of no significance (15) large AGs may cause symptoms related to venous hypertension (1). In this study, most of our patients had symptoms due to severe diseases such as subarachnoid or intraparenchymal hemorrhage, cerebrovascular attack and mass. We could not determine symptoms associated with AG, as most of our patients were already symptomatic relevant other than venous hypertension. Because of the retrospective basis of the study, clinical follow up of the patients was also limited. So, we could not associate symptoms such as vertigo and headache with AGs either. This was the main limitation of our study. The aim of this study was to determine the frequency of AG and any correlation with age and sex in MDCT. To define symptoms of AGs, more studies on patients with venous hypertension which compare size of AGs and symptoms are required.
Conclusions
As imaging technologies continue to develop, the frequency of normal variants such as AGs will probably increase. AGs are a common normal variant that appear as round or oval shaped well-defined filling defects with uni-or multilobulated contours. Radiologists should be aware of them, and they should not be mistaken for pathological intra-sinus lesions. The relationship between characteristics of the variant (presence, number, size) and of the human subjects (gender, age) should be reviewed with larger samples.

REFERENCES