Image Quality of Multisection CT of the Brain: Thickly Collimated Sequential Scanning versus Thinly Collimated Spiral Scanning with Image Combining

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ORIGINAL RESEARCH

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BACKGROUND AND PURPOSE: Routine CT of the brain is traditionally performed with sequential CT. We assessed whether sequential CT can be replaced with thinly collimated multisection spiral CT without loss of image quality.

MATERIALS AND METHODS: An observer study was conducted using data from 23 patients who were scanned with both a sequential (collimation, 4 × 5 mm) and a spiral technique (collimation, 4 × 1 mm; pitch, 0.875). Each sequential image was registered with 4 combined spiral CT images at 1.2 mm distance. Two neuroradiologists blindly scored 232 image pairs on 6 aspects: streak artifacts, visualization of brain tissue near skull, visualization of hypoattenuated lesions, gray/white matter differentiation, image noise, and overall image quality. A 5-point scale (range, −2 to 2) was used to score the preferences. The 23 pairs of complete scans were scored likewise. In this case, no registration was performed.

RESULTS: Virtually all mean scores were positive (ie, showed a preference for the spiral technique). For the comparison of image pairs, the preferences with respect to streak artifacts (mean score, 1.36), visualization of brain tissue near the skull (mean score, 0.69), and overall image quality (mean score, 0.95) were significant ($P < .001$). With respect to visualization of hypo-attenuated lesions, image noise, and gray/white matter differentiation (mean scores, 0.18, 0.27, and 0.13), the preferences for spiral CT were not significant. The preferences for the spiral technique were also present at the comparison of the complete scans.

CONCLUSION: Thinly collimated multisection spiral CT of the brain with image combining is superior to thickly collimated sequential CT.

Since the introduction of CT in 1972, routine CT scans of the brain have usually been made with a sequential technique. In 1989, spiral CT was introduced, and in 1991, multisection spiral CT. These developments made scanning with thin sections feasible. Thinly collimated multisection spiral CT has been applied in situations in which speed and a high spatial resolution in all 3 directions are important in, for example, CT angiography of the cerebral arteries. It is perhaps surprising that, until now, spiral CT has not replaced sequential CT on a large scale for routine examinations of the brain.[1] This is partly because of historical reasons and practical limitations, such as the limited heat capacity of the x-ray tube and the increased reconstruction time, and partly because there are some unresolved issues with regard to the image quality.

The image quality of spiral CT of the brain has been compared with sequential CT in a number of studies,[2-5] but it remains unclear whether the image quality of spiral CT is good enough to replace sequential CT. Bahner et al[2] concluded that sequential CT was superior to spiral CT in the assessment of small structures in a low-contrast setting and that artifacts close to the skull were present in spiral CT. Kuntz et al[3] stated that the image quality of spiral CT scans is comparable with or only slightly lower than that of sequential scans. These 2 studies, however, were not performed with thinly collimated spiral CT; a collimation of 8 mm was used for both the sequential scan and the spiral scan. Alberico et al[4] and Dorenbeck et al[5] showed that thinly collimated spiral CT scans are superior to sequential CT. These studies were restricted to scans of the skull base, however, and the image quality of spiral CT of the complete brain was not investigated. Moreover, in these last 2 studies, sequential and spiral scans were made with different tube voltages, different milliampere-second (mAs) settings, and different patients. The image quality of thinly collimated sequential CT of the brain has been compared with that of thickly collimated sequential CT by Jones et al.[6] They concluded that thinly collimated CT results in less posterior fossa artifacts. The section thickness used in this study, however, was 2.5 mm and therefore still relatively thick.

The above-mentioned studies[2-5] give some indications on the potential of spiral CT of the complete brain for the replacement of axial CT, but no definite conclusions can be drawn because of the methodologic shortcomings discussed above or because the study was limited to the skull base region only. Therefore an observer study was conducted in which the relevant aspects of the image quality of a *complete* brain examination were judged for both techniques. The purpose of this study was to assess whether sequential CT can be replaced with thinly collimated multisection spiral CT without loss of image quality.

Materials and Methods

CT Scans

Nonenhanced brain CT scans, both sequential CT and spiral CT, were made of 24 consecutive patients. The patients' physicians requested

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Table 1: Indications for scanning the brain.

Indication	No. of Patients
(Rule out) hydrocephalus	9
Stroke	6
Memory deficit	6
(Rule out) hematoma	4
Gait disturbance	3
Sensory deficit	2
Epilepsy	1
Vertigo	1

Note:—Some patients had multiple indications.

all examinations. Both inpatients and outpatients were included. Trauma patients were excluded. Details about the indications for the CT scans are given in Table 1. This prospective study, which included the addition of the spiral CT scan to the standard sequential scan for brain CT, was approved by our institutional review board, and informed consent was obtained from all patients. Human subjects were used because it is virtually impossible to design a phantom that is able to reveal all differences between the 2 scanning techniques when depicting the brain. Scans from 1 patient were excluded because not all scan parameters matched the protocol. The mean age of the remaining patients (11 women and 12 men) was 69 years (SD, 10 years; range, 48–84 years).

Scans were made with a multisection CT scanner (Mx8000 Quad; Philips Medical Systems, Best, The Netherlands). First, the standard sequential CT scan was performed and immediately thereafter the spiral CT scan was performed. For sequential CT, a collimation of 4 × 5 mm and a scan increment of 20 mm was used. For spiral CT, a collimation of 4 × 1 mm and a pitch of 0.875 was used. X-ray tube rotation time was 0.75 seconds for spiral CT and 1.5 seconds for sequential CT. Reconstructions were made with an additional, iterative beam-hardening correction[7] (UltraImage option). Reconstruction increment was 0.6 mm for spiral CT. Tube voltage (120 kV), effective mAs value (250 mAs), field of view (210 mm), and image matrix (512 × 512) were equal for both scans of each patient. Effective dose values were estimated with a CT dosimetry spreadsheet (ImPACT, London, United Kingdom; http://www.impactscan.org) based on Monte Carlo simulations.[8] The dose for a scan with a length of 140 mm was 1.1 mSv for the sequential technique and 1.5 mSv for the spiral technique.

To reduce the amount of radiation to the eyes, brain CT scans are often made with a tilted gantry. The use of a gantry tilt, however, may affect the image quality of spiral CT images.[9] For this study, therefore, we limited the gantry tilt to approximately 20° (the maximum possible gantry tilt is 30° on our scanner). This was compensated, if necessary, by tilting the chin of the patient toward the chest. The gantry tilt (mean value, 11.6°; SD, 4.9°; range, 0–18°) was equal for both scans of each patient.

Image Processing

The section sensitivity profile (SSP) of each scan technique was measured by scanning a small tungsten carbide sphere (diameter, 0.28 mm; New England Miniature Ball Corp, Norfolk, Conn). The profiles are shown in Fig 1. As a measure of the section thickness, the full width at half maximum (FWHM) of the SSP was used. The section thickness was 4.6 mm for the sequential technique and 1.4 mm for the spiral technique. By combining 4 spiral images with an in-between distance of 1.2 mm, a profile was obtained with a thickness of 4.8 mm.

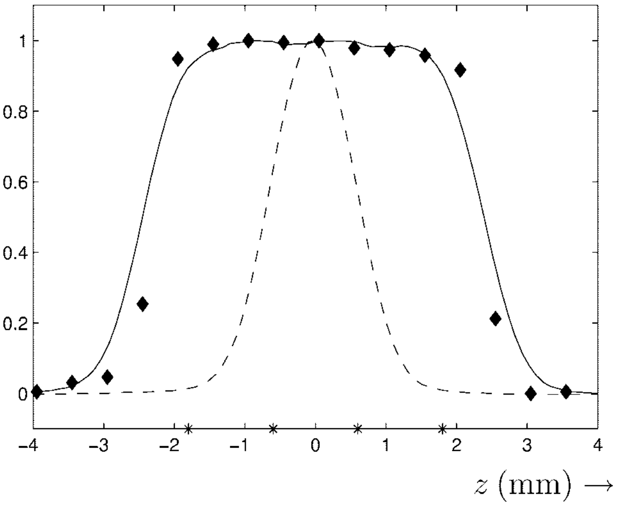

Fig 1. Section sensitivity profiles for sequential mode (*diamonds*) and spiral mode (*dashed line*). The continuous line depicts the profile of 4 combined spiral mode images with an increment of 1.2 mm (positions of each image given by asterisks on the z-axis).

Because of the inevitable movements of the patient between the sequential and spiral CT scan, corresponding sections often depicted slightly different locations of the patient's brain. To be able to compare 2 images with identical anatomy (see observer study below), the spiral CT scan and the sequential CT scan were registered. For each sequential image, a counterpart from the spiral dataset was determined by combining 4 corresponding multiplanar reformatted spiral images at 1.2-mm distance. The location and orientation of the MPR images was determined by minimizing the sum of squared differences of the CT value in the combined spiral images and the CT value in the sequential image with the downhill simplex method.[10] When reformatting the spiral CT images, cubic interpolation was used. Instead of registering the brain tissue, the bone was registered, using voxels with a CT value between 300 and 1000 HU. In this way, a slightly higher accuracy seemed to be obtained than when using the brain tissue itself in the registration procedure.

Probably as a result of calibration differences, the CT values of the brain tissue were slightly higher for the spiral technique than for the sequential technique. To be able to display images made with both techniques with the same setting for window width and window center for each patient, the CT values of the spiral images were lowered with a constant value to match the CT values of the sequential images. This overall shift was determined by minimizing the sum of squared differences between the CT values of the sequential images and the CT values of the registered spiral images. The mean shift was 7.0 HU (SD, 1.0 HU; range, 5–9 HU).

There seemed to be systematic differences between the sequential and spiral scans in the depiction of the soft tissue and skin outside the skull that could possibly affect the blindness of the study. Therefore, all structures outside the skull were removed by using thresholding and region growing techniques.[11]

Observer Study

Images of the skull base that are obtained with the thickly collimated sequential technique are often easy to distinguish from images that are obtained with the thinly collimated spiral technique because of the streak artifacts that may show up more prominently in the thickly collimated scans.[4,5] In the present study, it appeared that in the upper cranium as well, systematic differences were present between the scan techniques. Because these artifacts could possibly introduce a bias when scoring other aspects of the image quality, individual image pairs were compared first. This way, the blindness of the study was preserved for image pairs without the above-mentioned artifacts. An advantage of the comparison of a large number of image pairs is that the differences between the 2 scan techniques could be assessed more sensitively. In the second part of the observer study, complete sequential and spiral CT scans were compared to more closely mimic the normal diagnostic situation.

Two neuroradiologists independently judged the images in a blinded fashion. Patient data and scan parameters were removed from all images. The images were displayed on a digital PACS system (Agfa-Gevaert, Mortsel, Belgium) with a window center of 30 HU and a window width of 70 HU.

For the first part of the observer study, the images from all patients were divided into 3 groups. The first group contained the images from all patients from the middle region of the brain, where no clear systematic information was present that could be used to distinguish sequential from spiral images. The second and third group contained images from all patients above and below this region, respectively. To reduce the total number of images to be scored, only even image numbers were used. The sequential image and the corresponding spiral image were paired and labeled A or B at random. All image pairs within each group were presented in a random order. The order of the groups, described above, was also the order in which the observers scored the image pairs.

The observers compared each image pair on 6 aspects: streak artifacts, visualization of brain tissue near skull, visualization of hypoattenuated lesion(s), gray/white matter differentiation, image noise, and overall image quality. The aspect "visualization of brain tissue near skull" refers to the depiction of intracranial tissue or fluid up to a distance of approximately 1 cm from the skull. Other studies have already shown that the image quality may be compromised when using thickly collimated CT for imaging the skull base and posterior fossa.[4-6] An adequate visualization of tissue or fluid adjacent to the calvaria is also important, for example, when the presence of small extra-axial fluid collections, cortical infarcts or hematomas, or subarachnoid hemorrhage has to be confirmed or ruled out. With respect to the "visualization of hypoattenuated lesion(s)," the observers had to judge the visualization of small lesions (ie, lesions with dimensions on the order of $\leq$1 cm), including lacunar infarcts.

For each aspect, a score on a 5-point scale had to be given: preference for image A, slight preference for image A, no preference, slight preference for image B, and preference for image B. For streak artifacts, gray/white matter differentiation, and visualization of hypoattenuated lesion(s), the observers had the additional option "not applicable."

In the second part, complete sequential and spiral studies were compared. No image registration was performed. For each sequential image, the 4 closest spiral images with an in-between distance of 1.2 mm were averaged (Fig 1). The CT values of the spiral images were shifted as described previously (see image processing above).

The 2 scans from each patient were labeled at random A and B. The same aspects on the 5-point scale were scored as in the first part of the observer study.

Statistical Analysis

The scores on the 5-point scale were converted into preferences for the sequential or the spiral technique: -2, preference for the sequential technique; -1, slight preference for the sequential technique; 0, no preference; $+1$, slight preference for the spiral technique; $+2$, preference for the spiral technique.

For both observers and both studies the mean score for each aspect was calculated. The statistical significance ($P < .05$) of the difference between sequential CT and spiral CT was determined with a paired Wilcoxon signed-rank test. As multiple tests were executed, the observed P values were corrected by the Bonferroni method.[12]

For each aspect in both studies, the interobserver agreement was calculated. For this calculation, the categories preference and slight preference were merged. The observations for which at least one observer had chosen the option not applicable were excluded. At first, the κ value was determined to measure the observer agreement. However, some κ values seemed to be exceedingly low despite an apparently good observer agreement. This was due to the distribution of data across the 3 (merged) categories.[13] Therefore, a prevalence- and bias-adjusted κ value (PABAK) was also determined.[14]

The guidelines from Landis and Koch[15] for the qualification of the strength of agreement indicated with κ values were used.

Results

First Part of the Observer Study

In total, 232 image pairs were scored on 6 image quality aspects by 2 observers. In Table 2, the scores are given. For all aspects, the mean score was positive, showing a preference of the observers for the spiral technique. The preferences with respect to streak artifacts, visualization of brain tissue near skull, image noise (for observer 2), and overall image quality were statistically significant.

To detect a possible influence of the gantry tilt on the image quality, we divided the patients into 2 groups. The first group, containing 8 patients, had a mean gantry tilt of 5.9° (range, 0.0–10.5). The second group, containing 15 patients, had a mean gantry tilt of 14.6° (range, 12.0–18.0). No significant difference was present between the mean score for the overall image quality in both groups (0.58 and 0.62, respectively). For the individual aspects, the mean scores also did not differ significantly between the 2 groups.

The largest differences between the 2 scan techniques were found with respect to streak artifacts (mean score, 1.35), visualization of brain tissue near the skull (mean score, 0.68), and overall image quality (mean score, 0.61). In Fig 2, 2 images are shown of the skull base. The sequential image in Fig 2*A* shows streak artifacts. In this case both observers had a preference for the spiral image in Fig 2*B*. The CT values of the brain tissue were often slightly increased on the sequential images, especially near the skull in the region of the upper cranium, as shown in Fig 3. With regard to the visualization of brain tissue near the skull, both observers had a preference for the spiral technique (Fig 3*B*).

With respect to the "overall image quality," it seemed that a particular score in this category correlated strongly with some specific aspects of image quality. Figure 4 shows an example in which both observers had a slight preference for the spiral image. The spiral image was also slightly preferred by both observers with regard to the visualization of brain tissue near the skull and image noise. No preference for the gray/white matter differentiation was present in this case.

The mean scores for the aspects visualization of hypoattenuated lesions, gray/white matter differentiation, and image

Table 2: Frequencies, mean, and SD of scores of observers in pairwise comparison of images (first part of observer study)

Aspects & Observers	−2	−1	0	1	2	NA	Mean	SD	*P*
Streak artifacts									
1	0	0	0	44	22	166	1.33	0.47	<.001
2	0	0	7	29	33	163	1.38	0.66	<.001
Visualization brain tissue near skull									
1	0	2	105	106	19		0.61	0.65	<.001
2	1	10	75	104	42		0.76	0.81	<.001
Visualization hypodense lesion(s)									
1	1	22	33	39	1	136	0.18	0.83	>.05
2	2	31	24	40	7	128	0.18	1.00	>.05
Gray/white matter differentiation									
1	1	8	182	32	0	9	0.10	0.43	>.05
2	3	53	70	84	5	17	0.16	0.87	>.05
Image noise									
1	1	49	92	90	0		0.17	0.77	>.05
2	1	52	52	115	12		0.37	0.90	<.001
Overall image quality									
1	1	28	64	103	36		0.63	0.90	<.001
2	3	42	35	118	34		0.59	0.99	<.001

Note:—NA indicates not applicable. Scores range from −2 (preference for sequential technique) to +2 (preference for spiral technique). The tabulated *P* values are the those of the Wilcoxon signed-rank test multiplied by 24, which is the total number of significance tests performed (Bonferroni correction).

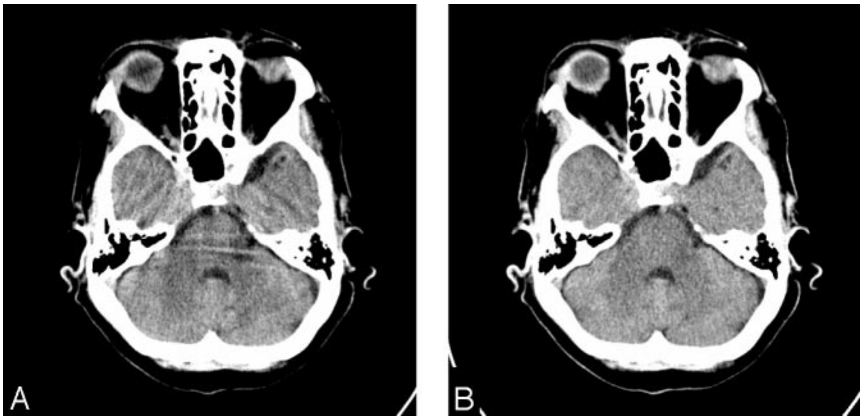

Fig 2. Cross-sectional images of the skull base.

A, Sequential technique. Severe streak artifacts are shown in the skull base.

B, Spiral technique.

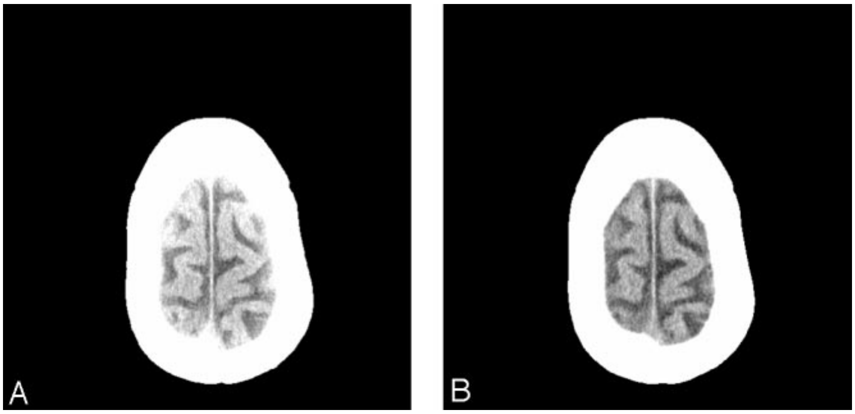

Fig 3. Cross-sectional images of the upper cranium.

A, Sequential technique. This image shows an increase of the CT values of the brain tissue, especially near the skull.

B, Spiral technique.

noise were relatively close to zero (0.18, 0.13, and 0.27, respectively).

Second Part of the Observer Study

In Table 3, the scores of both observers for the second part of the observer study are given. Again, the mean score was positive for all aspects, showing a preference for the spiral technique (except for observer 1 with respect to image noise). The preferences with respect to streak artifacts, visualization of brain tissue near skull, gray/white matter differentiation (for observer 2), image noise (for observer 2), and overall image quality were statistically significant.

Interobserver Agreement

In Table 4 the interobserver agreement is given for the first part of the study (columns 2–4) and the second part of the study (columns 5–7). For the judgment of the amount of agreement, the PABAK values were used, if available. In the

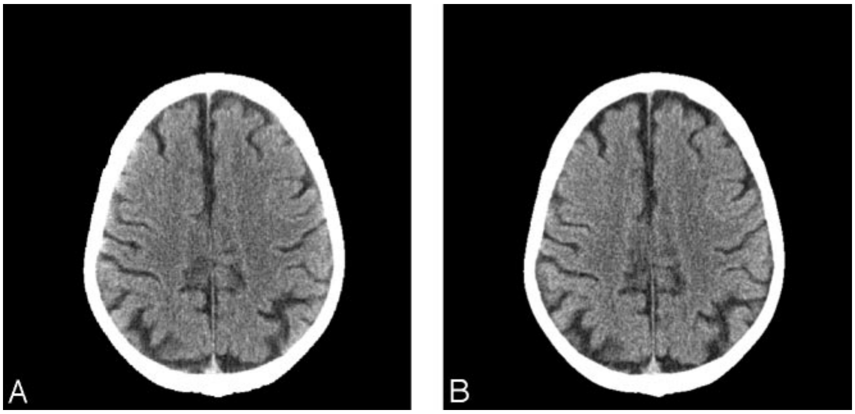

Fig 4. Cross-sectional images of the middle region of the brain. The spiral image has a higher contrast between the gyri and the CSF in the frontal region. Both observers had a slight preference for the spiral image with respect to "overall image quality," "visualization of brain tissue near the skull," and "image noise."

A, Sequential technique.

B, Spiral technique.

Table 3: Frequencies, mean, and SD of scores of observers in comparison of complete scans (second part of observer study)

Aspects & Observers	−2	−1	0	1	2	NA	Mean	SD	*P*
Streak artifacts									
1	0	0	0	18	5	0	1.22	0.41	<.001
2	0	0	0	3	20	0	1.87	0.34	<.001
Visualization brain tissue near skull									
1	0	0	2	21	0		0.91	0.28	<.001
2	0	0	0	16	7		1.30	0.46	<.001
Visualization hypodense lesion(s)									
1	0	0	10	5	1	7	0.44	0.61	>.05
2	0	1	6	8	0	8	0.47	0.62	>.05
Gray/white matter differentiation									
1	0	0	22	1	0	0	0.04	0.20	>.05
2	0	0	3	20	0	0	0.87	0.34	<.001
Image noise									
1	0	4	17	2	0		-0.09	0.50	>.05
2	0	0	0	4	19		1.83	0.38	<.001
Overall image quality									
1	0	0	0	21	2		1.09	0.28	<.001
2	0	0	0	1	22		1.96	0.20	<.001

Note:—NA indicates not applicable. Scores range from −2 (preference for sequential technique) to +2 (preference for spiral technique). The tabulated *P* values are the those of the Wilcoxon signed-rank test multiplied by 24, which is the total number of significance tests performed (Bonferroni correction).

Table 4: Interobserver agreement

Aspect	Observer Study: First Part			Observer Study: Second Part		
	N	κ	PABAK	*N*	κ	PABAK
Streak artifacts	60	0.00	0.88	23	0.00	1.00
Visualization brain tissue near skull	232	0.37	0.52	23	0.00	0.87
Visualization hypodense lesion(s)	71	0.09	0.11	15	−0.10	0.10
Gray/white matter differentiation	211	0.01	0.00	23	0.01	—*
Image noise	232	0.14	0.16	23	0.00	—*
Overall image quality	232	0.20	0.35	23	0.00	1.00

Note:—PABAK indicates prevalence- and bias-adjusted κ.
* No meaningful value could be determined because one or more of the concordant values of the cross-table became negative.

first part of the study, the agreement with respect to the streak artifacts and the visualization of brain tissue near the skull was almost perfect and moderate, respectively. With respect to the overall image quality, there was fair agreement. With respect to the visualization of hypoattenuated lesions and image noise, there was slight agreement. With respect to gray/white matter differentiation, there was no more agreement between the observers than could be expected based on chance.

The observer agreement in the second part of the study was (almost) perfect with respect to the streak artifacts, the visualization of brain tissue near the skull, and the overall image quality. With respect to the visualization of hypoattenuated lesions, there was slight agreement. For the remaining aspects, gray/white matter differentiation and image noise, no meaningful PABAK value could be determined (Table 4).

Discussion

Observer Study

Two observers compared in a blinded fashion the image quality of sequential CT images (with a section thickness of 4.6 mm) with the image quality of thinly collimated spiral CT images, which were combined to obtain approximately the same section thickness. With respect to nearly all aspects of the image quality, both observers had a preference for the spiral technique. For the other aspects, no statistical significant differences between the techniques were present.

The preference for the spiral technique was most clear with regard to the absence of the streak artifacts, the better visualization of the brain tissue near the skull, and the better overall image quality. Images made with the sequential technique often showed severe partial volume artifacts in the skull base. These artifacts were caused by attenuated bone structures that are only partly present in the section that is imaged.[16] When the collimation was reduced from 5 mm at sequential CT to 1 mm at spiral CT, these partial volume artifacts were reduced considerably. The reduction of partial volume artifacts in the skull base with reduction of section thickness was also found in earlier studies, both for thinly collimated spiral[4,5] and sequential CT.[6]

We did not find the artifacts in the brain tissue at the edges of the bones that were present in the spiral images in the study of Bahner and colleagues.[2] These artifacts were probably due to the relatively large section thickness of 8 mm used in that study, which can be expected to result in relatively large artifacts at bone edges due to the interpolation that is used in spiral CT. In our study, the effective section thickness was substantially smaller (1.3 mm). This reduces these artifacts considerably. Therefore, these artifacts were not present in the spiral CT images in the present study (Figs 3*B* and 4*B*).

The suboptimal visualization of brain tissue due to the increase of the mean CT value of the brain tissue near the top of the skull in standard sequential CT (Fig 3*A*) is a finding that, to our knowledge, has not been reported before. This increase of the CT values could possibly be ascribed to averaging of brain and skull in the relatively thick sections of sequential CT. However, a comparison with the combined, thinly collimated spiral CT images, which have a virtually identical section sensitivity profile, shows that this is not the case. The phenomenon can neither be explained by an incomplete correction of beam-hardening, because the same beam-hardening correction has been applied for both techniques, and the artifact appears only in the sequential technique. In our opinion, the artifact was caused by the partial volume effect, which also causes the streak artifacts in the skull base. In the upper part of the brain, it is caused by the slant angle of the bone relative to the scan plane. Because of the approximate circular symmetry of the skull, these artifacts show up as a general increase of the CT values of the brain tissue and not as streak artifacts, as in the skull base.

There was only a slight preference for the spiral technique with respect to image noise, gray/white matter differentiation and visualization of hypoattenuated lesions. The observer agreement for these aspects was relatively low. This can be explained by the subtleness of the differences between the techniques.

Before the comparison of the images, we registered the spiral scan with the sequential scan. This way, corresponding images depict identical anatomic structures, which has the advantage of a more accurate comparison. In some cases, small amounts of mismatch were present that might be caused by a slight motion of the patient during data acquisition. In particular, the appearance of small hypoattenuated lesions could be sensitive for these small mismatches. However, the quality of the match appeared satisfactory. Even if a slight amount of mismatch had been present in individual cases, no systematic bias would have been introduced.

In general, the outcomes of the comparisons of the complete scans were in good agreement with the outcomes of the comparisons of the individual images. For the complete scans, the judgment of the overall image quality of the sequential technique might be influenced by the streak artifacts in the skull base and hyperattenuated brain tissue near the skull in the upper cranium. This was not the case in the comparison of image pairs without these artifacts. This may explain the less strong overall preference for spiral CT in the first part of the observer study and the better observer agreement in the second part of the study with respect to the visualization of brain tissue near the skull and the overall image quality.

Clinical Relevance

With the CT scanner used in this study, the mean scan time of a thinly collimated spiral CT scan of the brain was 30 seconds, approximately 2 times longer than the mean scan time of a thickly collimated sequential CT scan. A minor disadvantage of this relatively long scan time is the increase of the risk of motion of the patient during data acquisition. In this study, at least 1 patient had moved during acquisition of the spiral scan, which affected the image quality and caused the observers to have a preference for the sequential technique. With the recent introduction of CT scanners with 16 to 64 detector arrays, this potential drawback will disappear because of the vastly reduced scan time.

Another potential drawback of thinly collimated spiral CT is the larger reconstruction time. Because of the relatively small reconstruction increment of the spiral scans, approximately 10 times more images are reconstructed. On our CT scanner, this resulted in an increase of the reconstruction time of approximately 4 minutes. With state-of-the-art CT scanners, which have a higher reconstruction speed, the additional reconstruction time will be negligible.

We used the same effective mAs value for the spiral scan and the sequential scan. By doing so, the amount of radiation used for both scans was the same. Consequently, the subjective noise level of the sequential and spiral scan was approximately equal. However, the geometric efficiency of the spiral technique, with a relatively narrow total beam collimation of 4 mm (4 × 1) mm, is worse than the efficiency of the broader beam collimation of the sequential technique of 20 mm (4 × 5 mm).[17] This resulted in an increase of the effective dose of approximately 35% when using the spiral technique instead of the sequential technique for the CT scanner used in this study.[8] Because the geometric efficiency improves when the total beam collimation increases, this disadvantage of thinly collimated spiral CT becomes insignificant when CT scanners with 16 or more thin detector arrays are used. The Mx8000 IDT 16-section CT scanner (Philips Medical Systems), for example, is identical to the scanner used in this study except for the number of sections. Scanning with this scanner with a beam collimation of 12 mm (16 × 0.75 mm) will result in an increase of the effective dose of only 11% compared with the sequential technique used in our study. If a beam collimation of 24 mm (16 × 1.5 mm) is used, the effective dose is the same (1.1 mSv) as that of the sequential technique.[8]

When replacing the sequential technique with the spiral technique, the effects on the cost of the examination should also be considered. It is unlikely that the increased scanning time and reconstruction time will lead to an increase of the costs of the examination, as the additional time for the scanning and reconstruction is relatively small compared with the total time allocated for the examination. After (automatic) image combining, the number of images to be judged by the radiologist is equal to the number of images of the sequential scan technique. Therefore, no additional costs are expected.

Although in the present study it was not attempted to judge whether the use of thinly collimated spiral CT would have resulted in another diagnostic outcome, we think that this possibly could be the case. With respect to the depiction of small subdural or epidural hematomas, for example, which were present or had to be ruled out in 3 patients in this study, the improved visualization of spiral CT could lead to a more accurate diagnosis. No differences were found in the present study with respect to the visualization of small hypoattenuated lesions, for instance lacunar infarcts, which were present in 7 of 23 patients in this study.

A clear advantage of thinly collimated spiral CT is the high spatial resolution in the longitudinal direction of the patient. This allows for high quality multiplanar reformation (MPR) in all desired planes.[18] Moreover, the high spatial resolution in all directions paves the way for the application of image processing techniques such as the registration of multiple scans. Registration of 2 or more CT scans of the same patient made at different moments will improve the visualization of the differences of anatomy or pathology between these moments, for example by making subtractions of the scans. Scans of hydrocephalus patients, for example, can be registered to determine the changes in the volume of the ventricles. Another possibility is the registration of CT scans of a patient with a brain tumor to visualize and quantify the course of the disease process. Differences will then no longer be obscured by variations in the depiction of the anatomy due to differences in the orientation of the patient's head in the CT scanner.

Conclusion

The image quality of thinly collimated spiral CT of the brain with image combining is at least as good as that of thickly collimated sequential CT and, in some aspects, better. The better visualization of brain tissue near the skull in the calvaria, and the improved overall image quality are new findings of this study. The reduction of image artifacts in the skull base obtained with the thinly collimated spiral technique is a confirmation of earlier studies.[4,5]

We conclude that, generally speaking, imaging of the brain should be performed with a thinly collimated spiral technique. For relatively old CT scanners, like the 4-section CT scanner used in this study, the slight increase in radiation dose and longer scan time are the only drawbacks of this technique. For state-of-the-art scanners, these disadvantages are absent.

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