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Contrast-Enhanced Spiral CT of the Head and Neck: Comparison of Contrast Material Injection Rates

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BACKGROUND AND PURPOSE: **Contrast-enhanced spiral CT studies of the head and neck are performed frequently using contrast material volumes of approximately 30 g iodine and a scan delay of 30–45 seconds. Because little is known about the effects of contrast material injection rates on tissue enhancement, this was prospectively investigated in our study.**

METHODS**: Ninety-seven patients underwent spiral CT of the head and neck. Each patient was assigned randomly to one of four groups who received 100 mL of nonionic contrast material (300 mg I/mL) at different monophasic injection flow rates with 1.5, 2, 3, and 4 mL/s. Scanning started after a constant delay of 35 seconds. The attenuation of the carotid artery, jugular vein, and sternocleidomastoid muscle was measured over time and the attenuation of the submandibular and thyroid gland was evaluated. Vascular attenuation of at least 150 HU was considered to be sufficient.**

RESULTS**: The mean scan time was 33 ± 5 seconds. The study, using an injection rate of 2 mL/s, showed the longest time of sufficient overall (arterial and venous) vessel attenuation (27 ± 4 seconds, $P \leq .008$). The injection flow rate did not influence significantly muscular attenuation (mean enhancement during scan time: 9 ± 7 HU). The 1.5 mL/s protocol showed the lowest attenuation values of the submandibular gland (81 ± 12 HU) and the highest attenuation values of the thyroid gland (164 ± 22 HU), but the attenuation of the thyroid gland was not statistically different from that revealed by the 2 mL/s protocol.**

CONCLUSION: **Using 100 mL of intravenous contrast material with 300 mg I/mL for spiral CT studies of the entire head and neck, the optimal injection flow is 2 mL/s, whereas lower flow rates resulted in insufficient venous enhancement.**

With the advent of spiral technology, scanning time has gradually decreased in CT studies of the head and neck during the last decade. This has allowed a more efficacious use of intravenous contrast materials.

Sufficient contrast enhancement of neck vessels is important for the adequate interpretation of head and neck CT. Controversy persists regarding the volume of contrast material necessary for spiral CT of the head and neck. Although some authors (1–4) proposed contrast material doses as low as 15 g iodine (equals approximately 50 mL contrast material containing 300 mg I/mL), doses of 25–35 g iodine (equals approximately 90–120 m contrast material containing 300 mg I/mL) are regarded as the standard doses necessary for adequate tissue attenuation in spiral CT studies of the head and neck (5–8). Little is known about the effects of contrast material injection rates on tissue enhancement in spiral CT studies of the head and neck.

The purpose of this study was to optimize contrast material injection rate when using 100 mL of contrast material containing 300 mg I/mL (30 g iodine) in spiral CT studies of the head and neck. Therefore, we designed a prospective study and evaluated the effects of different contrast material injection rates on tissue enhancement.

Methods

Between January and November 1998, 100 consecutive patients were referred for spiral CT of the head and neck at our institution. The majority of the patients was examined to evaluate the cervical lymph node status, to assess suspected nasopharyngeal or laryngeal tumor, or to follow up after tumor therapy. Three patients were excluded from the evaluation because of technical mistakes during image acquisition (wrong slice thickness in two patients, false scan delay in one patient).

The study population consisted of 97 patients (24 female, 73 male) who ranged in age from 30 to 85 years (mean age:

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From the Department of Radiology (R.G., P.W., G.J.S., R.M., F.S., M.M.U., M.T., B.G.), University Hospital Graz, Graz, Austria.

Address reprint requests to Reinhard Groell, MD, Department of Radiology, University Hospital Graz, Auenbruggerplatz 9, A-8036 Graz, Austria.

Table 1: Patient characteristics

	Patients				Contrast Material		
Protocol	*n* (f/m)	Age* [years]	Weight* [kg]	Height* [cm]	Volume [mL]	Injection rate [mL/s]	Duration of injection [s]
1	24 (5 f/19 m)	59 ± 15	70 ± 14	170 ± 7	100	1.5	67
2	24 (6 f/18 m)	58 ± 14	67 ± 14	171 ± 9	100	2	50
3	25 (6 f/19 m)	58 ± 13	69 ± 14	170 ± 10	100	3	33
4	24 (7 f/17 m)	56 ± 17	70 ± 13	171 ± 8	100	4	25

Note.—F/m indicates female/male. Scanning started 35 s after commencement of injection.
* Indicates mean ± standard deviation.

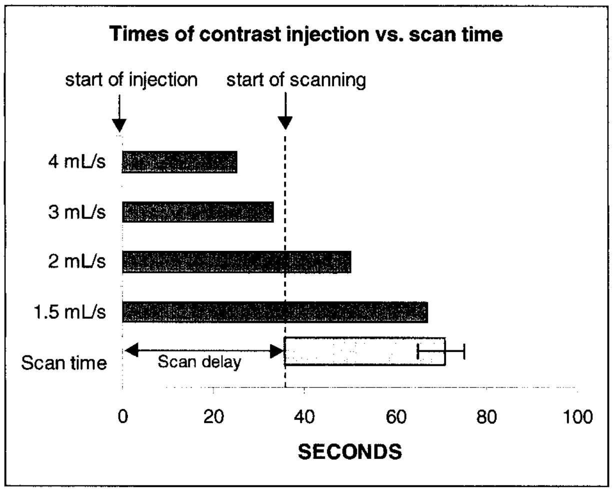

FIG 1. Times of contrast material injection versus scan time in four protocols with different contrast material injection rates.

59 ± 12 years). Their weight ranged from 46 to 105 kg (mean weight: 69 ± 14 kg), their height from 150 to 189 cm (mean height: 171 ± 9 cm).

All CT scans were performed in the spiral mode (Somatom Plus4, Siemens, Erlangen, Germany) using a 1-second rotation time. The scanning volume covered the area from the skull base to the thoracic inlet in the cephalo-caudad direction. The patients were lying in the supine position. All studies were performed with a 3-mm slice thickness and a 4.5-mm/s table speed (pitch 1.5) with images reconstructed every 3 millimeters. Each patient received a total of 100 mL of nonionic contrast material (iopromide 300 mg Iod/mL, Ultravist®, Schering, Berlin, Germany) administered by power injector (MCT, Medrad Inc., Pittsburgh, PA) through an intravenous cannula located in an antecubital vein. The patients were randomized into four groups who received the same amount of contrast material at four different rates of injection using 1.5 (n = 24), 2 (n = 24), 3 (n = 25), or 4 (n = 24) mL/sec (Table 1). In all patients, scanning started after a delay of 35 seconds after the commencement of injection (thus resulting in different bolus amounts before scanning was started) (Fig 1). During scanning, the patients were instructed to breathe normally but not to swallow. Analysis of variance revealed no significant differences between the four patient groups with respect to age (P = .877), weight (P = .407), height (P = .948), and sex (P = .774).

Image analysis was performed on a digital image workstation. The attenuation of the carotid artery, the internal jugular vein, and the sternocleidomastoid muscle was evaluated every fifth level (every 3.3 seconds) using a circular region-of-interest cursor. In all patients, the left-sided carotid artery, jugular vein, and muscle were measured except for in certain patients (n = 19) in whom the right side of the neck was used for the calculation. One reason for exclusion was the left internal jugular vein was too small or absent or the patient had undergone left-sided neck dissection. The relative variations of vessel attenuation (standard deviation as percentage of mean absolute attenuation) were similar in each patient group with different injection protocols, which indicated that the hemodynamic situations were comparable between the four groups. At the most cephalad levels, the temporal muscle was taken for evaluation of the muscles until the sternocleidomastoid muscle appeared. The attenuation of the submandibular and of the thyroid gland was measured when they were visible.

According to the results of a consensus conference (7), vessel attenuation of at least 150 HU was regarded as sufficient for spiral CT studies of the head and neck. The time span was evaluated when the great cervical vessels exceeded the 150 HU level. This was determined for the carotid artery and for the internal jugular vein, respectively. Additionally, the time span was evaluated when the attenuation of both carotid artery and internal jugular vein simultaneously exceeded 150 HU. This was referred to as the time span of sufficient overall vessel enhancement.

To analyze muscular attenuation, the first and last two measurements were averaged. These values, as well as their differences (muscular enhancement during scan time), were compared between the different injection protocols.

One-way analysis of covariance (ANCOVA) was performed to evaluate the effect of the protocol after adjusting the tissue attenuation response for the effect of the covariate ''weight.'' We investigated further to learn if the regression of the response on weight is the same for all groups. This assumption of equality of regression slopes was tested by fitting a model containing main effects of protocol and weight as well as an interaction term.

The global hypothesis—whether or not there is protocol effect after adjusting for weight—was tested with the F-test for ANCOVA. In the case of rejecting the global hypothesis, post hoc comparisons (Bonferroni procedure) were performed to detect which protocols differed significantly. All statistical analyses were performed with a standard personal computer software package (SPSS 8.0, SPSS Inc., Chicago, IL).

Results

The mean scanning time (33 ± 5 seconds) did not differ significantly between the protocols at the 5% level of statistical security. No severe adverse contrast reaction occurred, only minor to moderate general sensations of heat, without obvious tendency with any of the four protocols.

Table 2 lists the times of sufficient attenuation of the carotid artery and of the jugular vein as well as the times of sufficient simultaneous enhancement of both vessels. Sufficient arterial attenuation was longest for the protocol using 2 mL/s injection

Table 2: Time span of sufficient (> 150 HU) vessel attenuation

			Time span of sufficient (> 150 HU) vessel attenuation		
Protocol	Injection rate [mL/s]	Duration of scan [s]	Carotid artery [s]	Jugular vein [s]	Overall [s]
1	1.5	33 ± 7	25 ± 6	20 ± 11	19 ± 10
2	2	34 ± 4	28 ± 6	29 ± 5	27 ± 4
3	3	32 ± 4	22 ± 7	24 ± 6	21 ± 7
4	4	33 ± 4	21 ± 7	23 ± 6	19 ± 7

Note.—Values are mean ± standard deviation.

flow. This was statistically significant in comparison to the 3 mL/s ($P = .020$) and the 4 mL/s ($P = .040$) protocol. The difference of sufficient arterial attenuation between the 2 mL/s, and the 1.5 mL/s protocol was not significant.

The times of sufficient venous attenuation were also longest for the protocol with 2 mL/s flow rate. This was significantly longer than with the 1.5 mL/s ($P = .003$) and 4 mL/s ($P = .050$) protocols, but showed no significant difference to the 3 mL/s protocols ($P = 0.117$) at the 5% level of statistical significance.

The time spans of adequate overall vessel attenuation, when both vessels (carotid artery and jugular vein) simultaneously exceeded the 150 HU level, were significantly longer for the 2 mL/s protocol than for all other protocols (protocol 2 versus 1, $P = .002$; protocol 2 versus 3, $P = .008$; protocol 2 versus 4, $P = .001$).

At the start of scanning (35 seconds after commencement of injection), the mean attenuation of the carotid artery was higher than 150 HU for all protocols except for the protocol with 1.5 mL/s, which exceeded the 150 HU level 38.3 seconds after the start of injection (Fig 2A). Similar findings were observed for the jugular vein that exceeded the 150 HU level when scanning started, except for the 1.5 mL/s protocol, in which venous enhancement exceeded the 150 HU level not before 45 seconds after the start of injection (Fig 2B).

Muscular attenuation did not reveal significant differences between the protocols. During the scan time, the sternocleidomastoid muscle showed an almost linear enhancement from 60 ± 6 HU to 68 ± 6 HU (mean enhancement, 9 ± 7 HU). This did not differ significantly between the different protocols or weight groups at the 5% level.

The attenuation of the submandibular gland (mean attenuation, 90 ± 19 HU) was lowest for the 1.5 mL/s protocol, but this was only significantly different from the 2 mL/s protocol (81 ± 12 HU versus 99 ± 16 HU, $P = .023$). In contrast, thyroid attenuation (mean attenuation, 154 ± 26 HU) was highest in the 1.5 mL/s protocol but showed only significant differences to the 4 mL/s protocol (164 ± 22 HU versus 144 ± 26 HU, $P = 0.018$).

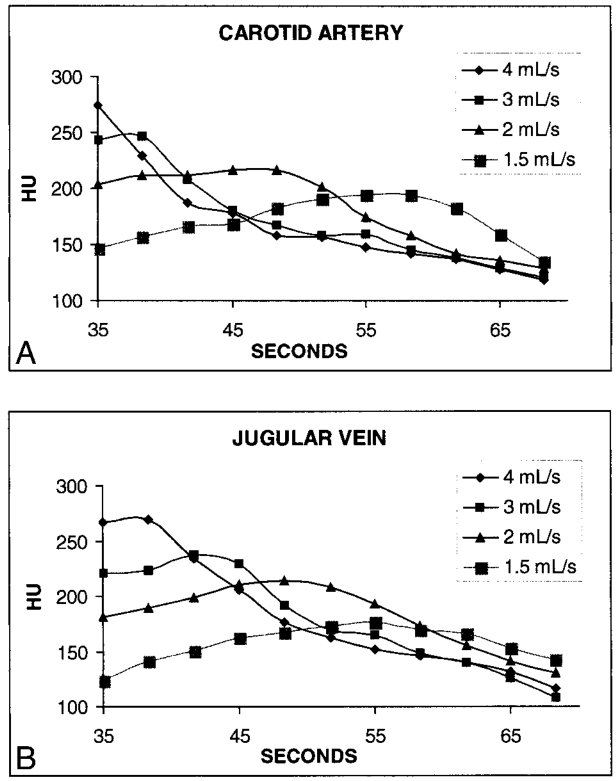

FIG 2. Mean time-density curves.

A and *B*, Curves of the carotid artery and the jugular vein with four protocols of different contrast material injection rates.

Discussion

In many institutions such as ours, spiral CT has become the method of choice for CT studies of the head and neck. For the proper interpretation of such studies, adequate enhancement of cervical structures, particularly of the cervical vessels, is necessary. The timing of CT studies of the head and neck, however, should fulfill two contrary requirements: it should be early enough to benefit from sufficient intravascular contrast material and it should be delayed enough to allow for adequate soft-tissue enhancement.

Most authors have proposed contrast material doses of approximately 25–35 g iodine and a scan delay of 30–45 seconds for optimal tissue opacification (5–9). Thus, the amount of contrast agent used in this study (30 g iodine) as well as the scan delay (35 seconds) are comparable to procedures at other institutions.

Our results suggest that the flow rate should not be lower than 2 mL/s to enable adequate enhancement, particularly of the cervical veins (Fig 3A–B). The injection protocol with 1.5 mL/s injection flow resulted in insufficient venous enhancement. Flow

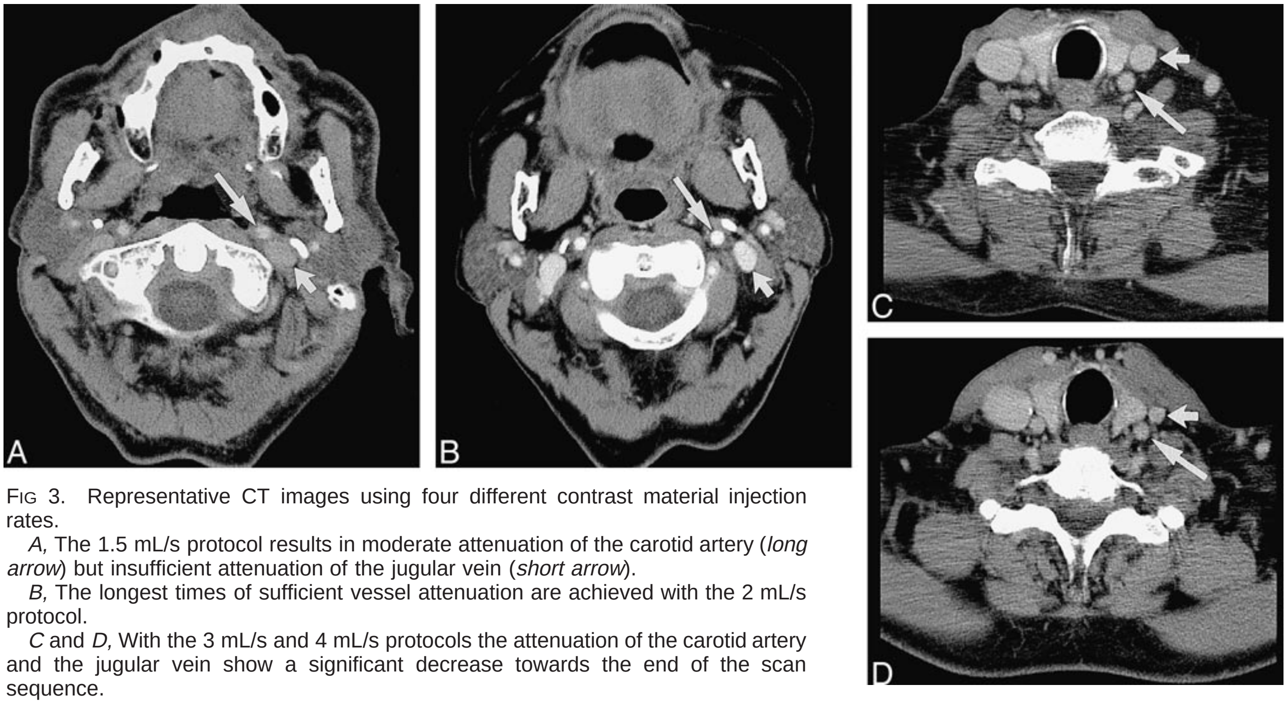

FIG 3. Representative CT images using four different contrast material injection rates.

A, The 1.5 mL/s protocol results in moderate attenuation of the carotid artery (*long arrow*) but insufficient attenuation of the jugular vein (*short arrow*).

B, The longest times of sufficient vessel attenuation are achieved with the 2 mL/s protocol.

C and *D,* With the 3 mL/s and 4 mL/s protocols the attenuation of the carotid artery and the jugular vein show a significant decrease towards the end of the scan sequence.

rates of 3 and 4 mL/s resulted in higher initial vessel attenuation but decreased the times of sufficient vessel attenuation (Fig 3C–D).

We consider attenuation values of cervical vessels of 150–200 HU as optimal with no considerable further improvement of vessel visualization when their attenuation values exceed the 200 HU level. Using standard window settings for CT of the head and neck that emphasize soft tissue contrast (at our institution: width, 350 HU; center, 50 HU) vessel attenuation of more than 250 HU might even result in decreased visualization of intraluminal abnormalities. In accordance with the results of a consensus conference, we believe that vascular attenuation of less than 150 HU leads to reduced contrast to adjacent soft-tissue structures, which may be problematic, particularly in the region of the skull base and the thoracic inlet (7).

The time-density curves (Fig 2A–B) of the cervical vessels reflect the mean values averaged between all patients within a protocol (24 or 25 patients per protocol). Although these curves demonstrate the difference of contrast enhancement between the various protocols, they do not reflect the variations of contrast enhancement within a protocol. Most parts of the mean venous time-density curve of the 24 patients examined with the 1.5 mL/s protocol (Fig 2A) run above the 150 HU level. This curve, however, neglects the fact that, in nine of the patients, the jugular vein exceeds the 150 HU level in less than 50% of the individual study time.

This study evaluated the effects of contrast material flow rates in studies of the whole head and neck region from the base of the skull to the thoracic inlet. The requirements for tissue enhancement might be different in patients with specific clinical questions; eg, when the region of scanning is restricted to the larynx or the mid-face. Although this was not evaluated directly in this study, our results might be of help in adapting contrast material injection parameters to these specific clinical demands. Moreover, our study was designed to optimize enhancement of vessels and normal tissues and not to evaluate pathologic conspicuity. The small number of proved lesions in our study did not allow for reliable comparisons between the protocols for lesion conspicuity.

A recent report discusses the value of delayed scans in spiral CT of the head and neck. Harris et al have shown greater conspicuity of certain neck lesions such as squamous cell carcinoma, lymphadenopathy, or pleomorphic adenoma of the parotid gland on images performed 10 to 15 minutes after the injection of contrast material (5). They proposed that a second bolus of an additional 50 mL of contrast agent administered immediately before the delayed scanning sequence might optimize tissue enhancement on delayed scans. This would, however, increase considerably the total amount of contrast agent (and radiation exposure) for spiral CT of the head and neck. To our knowledge, a systematic comparison of early and delayed scans has not been performed yet for spiral CT of the head and neck. Thus, it remains unclear whether delayed scans are useful as a routine protocol in spiral CT studies of the head and neck or whether they should be reserved for certain patients with known lesions of the cervical region.

Conclusion

The optimal injection flow is 2 mL/s to provide adequate contrast enhancement of the cervical vessels and soft tissues in spiral CT studies of the head and neck for 100 mL of intravenous contrast material with 300 mg I/ml (30 g iodine) and a scanning delay of 35 seconds. The injection protocol with lower injection flow (1.5 mL/s) resulted in insufficient venous enhancement.

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