Purpose: In order to explore the utility of fast spin-echo techniques in the neck, 50 consecutive conventional spin-echo (CSE) long TR examinations were compared with 50 consecutive fast spin-echo (FSE) long TR scans for cervical lymph nodes.

Materials and Methods: Standard CSE examinations used parameters of 2200/80/1 (TR/TE/excitations), 256 x 128 matrix, 5 mm thick with interslice gaps between 1 and 2.5 mm. FSE studies were employed with TR of 4000/80/2, 256 x 192 matrix, fat suppression and 5 mm contiguous slices. Standard T1-weighted examinations and clinical correlation were used as proof of nodal presence.

Results: Overall vascular flow artefacts, patient motion artefacts, and image quality were comparable between the two techniques. Lymph node detectability was superior with FSE scans (P < 0.05). Typical time saved was approximately 4.5 min with FSE, despite the use of larger matrices, contiguous slices and twice the excitations.

Conclusion: FSE is a competitive technique to CSE images in the neck, yielding similar quality images with higher resolution, reduced scan time, and improved lymph node detectability.


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The technique of fast spin-echo (FSE) or rapid acquisition relaxation enhancement (RARE) imaging [1-3] has been applied to the brain and spine with considerable success [4-8]. The main advantage of the technique is the rapid acquisition of high quality proton density and T2-weighted (T2W) images without significant degradation of signal-to-noise ratio or contrast resolution. Additionally, because of the savings in time, one has the option of increasing signal to noise by increasing the number of excitations, increasing the T2-weighting by prolonging the repetition time, or performing high resolution MR images with a larger matrix size.

In the neck, where rapid image acquisition is critical due to the large scanning range that is required (from the base of the skull to the upper mediastinum), conventional spin-echo long TR sequences suffer due to their long scan times. Motion artefacts from swallowing, breathing and patient restlessness are compounded with long scan times. Because patients with head and neck malignancies may have difficulty breathing in the supine imaging position from airway obstruction or retained secretions, rapid imaging is even more critical. In order to cover the entire scan range required, it is often necessary to increase the slice thickness and/or the interslice gap. However, since MR must be competitive with CT in the evaluation of neck pathology, it would be preferable to obtain 5 mm-thick contiguous sections similar to those obtained with CT. With standard long TR pulse sequences, this requires interleaving of two sequences and, because of the double acquisition, scan times are doubled. One often is forced to decrease matrix sizes (leading to decreased resolution), perform 1/2 excitation imaging, or face 15-20 min T2W scans.

These factors point to the great potential for FSE imaging in the neck. Scan times are reduced, slice thicknesses can remain competitive with CT and, with fat suppression techniques applied, contrast is high. FSE's utility in the neck remains unexplored and this has led to the current study.

In order to investigate the potential of FSE imaging in the neck, we compared 50 consecutive patients with conventional spin-echo scans through the neck with 50 consecutive patients with the fast spin-echo technique. The two techniques were compared for the following parameters: diagnostic quality, patient motion artefact, carotid and jugular flow artefacts, nodal detectability and scan times. We chose to study lymph node detectability because this is a common indication for scanning and would eliminate the need to control for primary site of tumour in a comparative study.

METHODS

MR scans from 50 consecutive patients who were evaluated for cervical lymphadenopathy using conventional spin-echo long TR images (before fast spin-echo was introduced at our institution) and 50 consecutive FSE scans were retrospectively and independently reviewed by two experienced head and neck radiologists. All patients had squamous cell carcinomas of the head and neck and were being evaluated for metastatic cervical lymphadenopathy.

Conventional spin-echo images employed a TR of 2000 to 3500 ms, TEs of 80-90 ms, single excitations, and fields of view from 20 to 24 cm. The imaging matrix used was...
Table 1 – Grading scale for various parameters

<table>
<thead>
<tr>
<th>Grade</th>
<th>Carotid flow artefact</th>
<th>Jugular vein artefact</th>
<th>Diagnostic quality</th>
<th>Patient motion</th>
<th>Detectability of lymph nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No artefact</td>
<td>No artefact</td>
<td>Diagnosis can be made</td>
<td>No artefact</td>
<td>Excellent detectability</td>
</tr>
<tr>
<td>1</td>
<td>Minimal motion or signal within vessel</td>
<td>Minimal motion or signal within vessel</td>
<td>Diagnosis cannot be made</td>
<td>Minimal motion</td>
<td>Fair detectability</td>
</tr>
<tr>
<td>2</td>
<td>Moderate motion but study interpretable</td>
<td>Moderate motion but study interpretable</td>
<td>Moderate motion but study interpretable</td>
<td>Moderate motion but study interpretable</td>
<td>Poor detectability</td>
</tr>
<tr>
<td>3</td>
<td>Flow artefact obscures anatomy and study uninterpretable</td>
<td>Flow artefact obscures anatomy and study uninterpretable</td>
<td>Motion obscures anatomy and study uninterpretable</td>
<td>Motion obscures anatomy and study uninterpretable</td>
<td>Poor detectability</td>
</tr>
</tbody>
</table>

Scans were graded on a 0 to 3 scale for evaluating motion artefacts. Zero represented no motion, 1 minimal motion which did not obscure visualization of the anatomy and 2 moderate motion without such obscuration of anatomy that the study was uninterpretable, and 3, motion obscuring anatomy to the extent that the study was uninterpretable.

Table 2 – Scores of all 50 cases

<table>
<thead>
<tr>
<th>Grade</th>
<th>Carotid flow artefact</th>
<th>Jugular vein artefact</th>
<th>Diagnostic quality</th>
<th>Detectability of Lymph nodes</th>
<th>Patient motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSE</td>
<td>0.41</td>
<td>1.04</td>
<td>0.11</td>
<td>1.13</td>
<td>0.52</td>
</tr>
<tr>
<td>FSE</td>
<td>0.30</td>
<td>1.02</td>
<td>0.14</td>
<td>0.82</td>
<td>0.73</td>
</tr>
<tr>
<td>t-statistic</td>
<td>-0.85</td>
<td>-0.10</td>
<td>0.43</td>
<td>-2.20*</td>
<td>1.57</td>
</tr>
</tbody>
</table>

* Statistically significant \( P < 0.05 \).

Using grade scale shown in Table 1, the scores from the two reviewers were averaged for the 50 FSE and CSE scans to obtain values in the table above. Note the carotid flow artefact, jugular flow artefact, patient motion artefact and diagnostic quality were not significantly different between CSE and FSE. Detectability of lymph nodes was statistically superior on FSE than CSE.
Fig. 1 – Grading of artefacts. (a) Non-diagnostic (grade 1) CSE study demonstrating patient motion artefact (grade 2) as well as vascular artefact from jugular veins causing obscuration of anatomy to the point where the study was uninterpretable (grade 3). (b) Axial 3000/80 fast spin-echo fat-suppressed scan in a patient with lymphoma demonstrating excellent detectability of lymph nodes and no significant vascular artefact. Retropharyngeal, high jugular and posterior triangular lymphadenopathy is evident.

same parameters as the 50 patient data set (jugular and carotid flow artefacts, patient motion, detectability of lymphadenopathy and diagnostic quality). For a statistically significant result assuming the same parameters above, but for 17 matched pairs of data, the power factor would be 0.65, moderate in significance.

RESULTS (see Table 2)

Fifty Patient Data Sets
The mean scan time for the fast spin-echo T2W scans in the 50 patients was 6.3 min. This compared with a mean scan time of 11.0 min for the conventional spin-echo technique. Therefore the mean time saving was 4.7 min.

When the studies were evaluated for the presence or
Fig. 3 - Comparison of CSE and FSE for nodal detection. (a) Axial 2200/90 CSE scan at the mandibular tip demonstrating adequate visualization of the lymph nodes around the left submandibular gland (arrow). The signal-to-noise ratio (SNR) and resolution are fair. (b) The lymph node to background contrast is excellent on this axial 4000/80 fat-suppressed FSE scan through the same level on the same patient. SNR is improved as well.

absence of patient motion, the average grading for the fast spin-echo technique was 0.73; however, it was 0.52 for the conventional spin-echo technique, not statistically significant. Non-diagnostic studies due to patient motion occurred with equal frequency on FSE (2) and CSE (2) scans.

Fig. 4 - Improved nodal detection with FSE vs CSE. (a) Axial fat-suppressed FSE scan (4000/80/2) showing bilateral lymph nodes posterior to the submandibular gland (arrows) in high jugular chains, graded 'excellent visualization'. Mild vascular artefact is seen on the right side emanating from the jugular vein. Scan time for 44 contiguous 5mm sections was 7 min. (b) Axial CSE (2000/90/1) scan also suffers from vascular flow artefact. Lymph node detectability was graded 'fair'. Scan time for 30 5mm sections with 1 mm interslice gaps was 10 min, 24 s.
Twenty-two of 50 CSE scans failed to cover the entire region of interest of a standard head and neck MR, from the cavernous sinus to the thoracic inlet-upper mediastinum. Four FSE scans were suboptimal in this regard.

Images were graded as being diagnostic in 44 of 50 (88%) fast spin-echo and 44 of 50 (88%) conventional spin-echo MR scans. Flow artefacts (6), poor fat suppression (2), and patient motion (4) accounted for the non-diagnostic studies.

The average grade for the fast spin-echo technique for the flow artefact within the carotid arteries was 0.30. For the conventional spin-echo the average grade was 0.41. In six cases the conventional spin-echo technique had sufficient signal within the artery so as to be labelled moderate in severity; this was present in only two FSE studies. There were no cases where carotid flow artefact obscured anatomy. For jugular flow artefacts, the mean FSE grade was 1.02 and for CSE was 1.04. There was no statistically significant difference between CSE and FSE in carotid or jugular flow artefacts. However, in seven FSE cases the jugular vein had sufficient artefact from flow signal in the phase encoding plane that it obscured anatomy; this was present in only one CSE case (Figs 1 and 2).

The FSE technique had a mean grade of 0.82 in the readers' ability to detect lymph nodes. The corresponding value of CSE was 1.13. The improved ability to detect lymph nodes with FSE was statistically significant to a P value < 0.05. Poor nodal detectability was noted in 18 CSE and eight FSE studies.

Comparative Studies Between CSE and FSE in Same Patient

When the CSE studies were compared directly with FSE studies of the same patients, the findings were essentially similar to the analysis of the 50 patient categories. The major findings noted were: (1) no statistically significant differences in jugular vein and carotid artefact scores; (2) two non-diagnostic FSE cases because of patient motion artefact, but all CSE cases were diagnostic; (3) improved nodal detectability with FSE over CSE in eight cases, equivalent conspicuity in six cases, and inferior detectability by FSE in three cases (Figs 3 and 4).

DISCUSSION

The fast spin-echo technique (previously known as rapid acquisition enhancement) offers the ability to reduce scan times to as much as 1/16th that of conventional spin-echo technique [1-4]. Typically, however, because scans are performed with multiple echoes the time saving is less than the full potential. The technique has generated a lot of enthusiasm because of the potential for increasing patient throughput while decreasing the flow artefact within the carotid arteries. For jugular flow artefacts, the mean FSE grade was 1.02 and for CSE was 1.04. There was no statistically significant difference between CSE and FSE in carotid or jugular flow artefacts. However, in seven FSE cases the jugular vein had sufficient artefact from flow signal in the phase encoding plane that it obscured anatomy; this was present in only one CSE case (Figs 1 and 2).

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Another of the curious characteristics of this technique that has been noticed is the high signal intensity of the fat on the long TE sequence [8,11]. The closely spaced 180° refocusing pulses cause a decrease in the contribution of fat to the T2 decay process leading to bright lipid signal [8]. For this reason, fast spin-echo images through the orbit and head and neck are generally performed with fat suppression. We chose to explore the fat-suppressed FSE technique in the neck in order to determine its utility vis-à-vis conventional spin-echo T2-weighted scans, since the long CSE scan times often lead to sub-optimal studies. The use of fat suppression raises the spectre of incomplete or inhomogeneous suppression which may degrade scan quality. This was a problem in 4% of our cases and can be obviated with the use of water bags filled with kaolin pectin or other 'sat-pads' currently on the market.

The proton density-weighted image, most helpful in evaluating cortical lesions in the brain, is of limited use in the MR evaluation of neck masses. Because of this, fast spin-echo images with a single long (T2-weighted) echo may be performed, thereby gaining a greater advantage with the fast spin-echo technique. With fat suppression, lesions which are inflammatory and have a high signal intensity on T2-weighted scans may be easily detected against dark fat, and lesions which are of intermediate signal intensity (most highly cellular malignancies such as squamous cell carcinoma) will still be of greater intensity than the suppressed fat. The lymph nodes in the neck, which are sometimes isointense with muscle and hard to see on short TR images, are well demonstrated as high signal intensity structures on T2-weighted scans. Detection of lymphadenopathy is one of the primary roles for T2W scans in the neck and that is why we chose to analyse this variable in our FSE vs CSE study.

Standard spin-echo images require flow compensation techniques such as gradient moment nulling in order to reduce the flow artefact from blood vessel pulsations. Employing gradient moment nulling (GMN) decreases the number of scans per TR because of the larger TE needed to apply the gradients to compensate for the flow [12]. This also decreases signal-to-noise ratio. However, GMN also yields high signal in slow flowing blood vessels which can lead to misdiagnosis of lymphadenopathy where jugular venous branches are outlined in fat. However, analysis of sequential images showing the tubular nature of the vessel should reduce this possible error. Our study has shown that the fast spin-echo technique does not require flow compensation to reduce flow artefacts to the equivalent status of conventional spin-echo images. Without GMN, the blood vessels remain black because of the saturation occurring with the rapid 180° pulse profiles. The flow artefacts are tolerable.

Ideally, this study should be followed with a prospective protocol performing CSE and FSE studies on all patients, who are matched for primary sites of tumour and staging, to assess the role of FSE for routine neck imaging. This would require a very large population of head and neck lesions to evaluate; for this reason we chose cervical lymphadenopathy alone. Because of the difference in image quality, blinding reviewers to the two types of scans is not possible. Also using another 'gold' standard for proof of adenopathy, such as pathologic confirmation rather than the remaining pulse sequences, would also be difficult to achieve retrospectively.
In this study we have demonstrated that the artefacts from patient motion, and jugular and carotid flow are comparable and not statistically significant between FSE and CSE images. Lymph node detectability shows a statistically significant \((P < 0.05)\) improvement with FSE over CSE. In addition, with FSE, one has the advantage of \(256 \times 192\) images (vs \(256 \times 128\) with CSE), two excitation scanning (vs one excitation with CSE) for improved signal-to-noise ratio, and contiguous \(5\) mm slices (vs \(1.0-2.5\) mm interslice gaps with CSE) while obtaining scan times that are \(4.5\) min shorter. Instead of skimping on full coverage of the neck (seen in \(23\) of \(50\) CSE studies presumably because of time constraints), full coverage from the base of the skull to the upper mediastinum can be obtained with FSE scans in \(6.3\) min. We believe the technique has tremendous potential in neck imaging and will replace CSE scans. If high resolution \((256 \times 256)\) images are required the technique can be adjusted with a continued benefit in time savings compared with conventional spin-echo technique.

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**REFERENCES**