MRI-Guided and CT-Guided Cervical Nerve Root Infiltration Therapy: A Cost Comparison

Kostenvergleich der MRT- und CT-gesteuerten periradikulären Schmerztherapie an der Halswirbelsäule

Purpose: To evaluate and compare the costs of MRI-guided and CT-guided cervical nerve root infiltration for the minimally invasive treatment of radicular neck pain.

Materials and Methods: Between September 2009 and April 2012, 22 patients (9 men, 13 women; mean age: 48.2 years) underwent MRI-guided (1.0 Tesla, Panorama HFO, Philips) single-site periradicular cervical nerve root infiltration with 40 mg triamcinolone acetonide. A further 64 patients (34 men, 30 women; mean age: 50.3 years) were treated under CT fluoroscopic guidance (Somatom Definition 64, Siemens). The mean overall costs were EUR 240 for MRI-guided interventions and EUR 124 for CT-guided interventions. These were (MRI/CT guidance) EUR 150/60 for equipment use (purchase, depreciation, maintenance, and energy costs), personnel costs and expenditure for disposables that were identified for MRI- and CT-guided procedures. Additionally, the cost of ultrasound guidance was calculated.

Results: The mean intervention time was 24.9 min. (range: 12 – 36 min.) for MRI-guided infiltration and 19.7 min. (range: 5 – 54 min.) for CT-guided infiltration. The average total costs per patient were EUR 240 for MRI-guided interventions and EUR 124 for CT-guided interventions. These were (MRI/CT guidance) EUR 150/60 for equipment use, EUR 46/40 for personnel, and EUR 44/25 for disposables. The mean overall cost of ultrasound guidance was EUR 76.

Conclusion: Cervical nerve root infiltration using MRI guidance is still about twice as expensive as infiltration using CT guidance. However, since it does not involve radiation exposure for patients and personnel, MRI-guided nerve root infiltration may become a promising alternative to the CT-guided procedure, especially since a further price decrease is expected for MRI devices and MR-compatible disposables. In contrast, ultrasound remains the less expensive method for nerve root infiltration guidance.

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Introduction

Cervical pain syndrome and radicular cervical spine pain are common clinical pictures and result in significant costs for health insurance companies and the economy [1, 2]. In patients for whom conservative treatment with physiotherapy and/or oral pain medication does not yield a satisfactory reduction in pain, minimally invasive nerve root infiltration with corticosteroids and anesthetics has proven successful as a further treatment option [3 – 7]. Although rare, severe complications, such as cervical spinal nerve root infiltration from the standpoint of the radiological department.


Materials and Methods

Patients

In a period from September 2009 to May 2012, 22 patients (9 men, 13 women, mean age: 48.2 ± 10.1 years, range: 32 – 77 years) underwent cervical nerve root infiltration under CT-fluoroscopic guidance via an open 1.0-Tesla MRI system (Panorama HFO, Philips, Best, The Netherlands). In the same period, 64 additional patients (34 men, 30 women; average age: 50.3 ± 10.0 years, range: 21 – 81 years) were treated via nerve root infiltration under CT-fluoroscopic guidance (Somatom Definition 64, Siemens, Erlangen, Germany). Preinterventional MRI imaging of the cervical spine showing a compression syndrome of a cervical nerve root was available for all patients. The patients had been referred to our clinic by a treating orthopedist or neurosurgeon due to correlating pain symptoms. Written informed consent was obtained from each patient following clarification of the treatment, possible complications, and alternative treatment methods. The MRI-guided periradicular infiltration treatment method was approved by the local ethics commission.

Nerve root infiltration therapy techniques MRI-fluoroscopic nerve root infiltration

Each patient was positioned in a side position on the MRI table with the side to be treated facing up. A multifunction surface coil was positioned over the target region of the patient orthogonal to main magnetic field B0 in order to achieve the highest possible MRI signal. An interactive PDw fast spin echo (FSE) sequence (TE/TR 10/600) almost in real time was used to anatomically locate the nerve root to be treated and to guide the injection needle. 2 ml of Xylonest 1 % (Lidocaine and 1 % adrenaline, AstraZeneca, Wedel, Germany) were applied subcutaneously for local anesthesia. After a point-shaped stab incision was made with a scalpel, an MRI-compatible 20G injection cannula (MREye®, Cook Medical, Limerick, Ireland) was inserted dorsolaterally through the soft tissue of the neck under MRI guidance until the tip was able to be positioned directly lateral to the border of the nerve root to be treated (Fig. 1). After a positioning check and a position correction as necessary, a mixture of 1 ml of triamcinolone acetonide (40 mg, Triam®, Winthrop Arzneimittel GmbH, Mühlheim, Germany) und 2 ml of Carbostesin (0.5 % bupivacaine hydrochloride, AstraZeneca, Wedel, Germany) was applied periradically. Proper distribution of the injectate was ensured with the help of a strong T2w fat-saturated FSE (SPIR, spectral presaturation with inversion recovery) sequence in axial slice orientation. An infiltration was considered technically successful in the case of proper distribution of the injectate in the periradicular space. After removal of the injection cannula, the puncture site was covered with adhesive tape. The patients were observed after the intervention for a period of 30 minutes. In the case of a lack of symptoms of aggravated pain or illness, the patients were discharged.
CT-fluoroscopic nerve root infiltration

Patients were positioned in a supine position on the CT table with the head in the direction of the gantry. A lateral overview image of the cervical spine was first acquired for treatment planning. Single CT scans (or a short spiral scan in individual patients) were then acquired under consideration of the CT scout to determine the correct height of the nerve root to be treated on the z-axis. A metal wire on the skin of the side to be treated provided orientation for determining the puncture position on the xy plane. The presumably correct injection site was marked on the skin with a felt-tip marker. After sterile covering and disinfection of the skin, local anesthesia was administered in the region of the planned puncture site (Xylonest 1 %, AstraZeneca, Wedel, Germany). A 22-gauge injection cannula (Becton Dickinson SA, S. Agustin del Guadalix, Spain, length 90 mm) was inserted under CT-fluoroscopic guidance using the “step and shoot” technique and its tip was advanced to the corresponding cervical nerve root directly in front of the respective facet while protecting the vertebral artery (Fig. 2). After removal of the interior trocar, a mixture of 2 ml of Carbostesin (0.5 % bupivacaine hydrochloride, Astra Zeneca, Wedel, Germany) and 1 ml of iodine-containing contrast agent (Accupaque 240, GE Healthcare, Munich, Germany) and 1 ml of iodine-containing contrast agent (Accupaque 240, GE Healthcare, Munich, Germany) was administered. The contrast agent was used to ensure proper distribution along the nerve root with homogeneous distribution in the periradicular space being considered a technically successful infiltration. 1 ml of triamcinolone acetonide (40 mg, Triam®, Winthrop Arzneimittel GmbH, Mühlheim, Germany) was then administered. The effective dose applied during therapy guidance (in millisievert, mSv) was approximated on the basis of the dose-length product (DLP) using the software CT-expo version 2.0.

Definition and calculation of costs

To calculate the total costs of the MRI-guided and CT-guided pain treatments, three different cost types including equipment usage costs, personnel costs, and material costs were used. The equipment usage costs included the costs for procurement, depreciation...
All MRI fluoroscopy and CT fluoroscopy-guided interventions were able to be performed with technical success. Fig. 3 provides an overview of the number of treatments at the different cervical nerve root locations for both procedures. The average intervention time for MRI fluoroscopy interventions was 24.9 ± 6.3 minutes (range: 17 – 36 minutes). Preinterventional patient preparation took an average of 22 minutes, while postinterventional activities took an average of 9 minutes. A CT fluoroscopy intervention took an average of 19.7 ± 7.9 minutes (range: 5 – 54 minutes) with an average of 20 minutes of preinterventional preparation and 9 minutes of postinterventional activities.

The approximated average effective dose for CT-guided interventions was 0.48 ± 0.51 mSv (range: 0.07 – 1.92 mSv). A CT spiral was necessary in 17 of 64 patients for better localization of the nerve root and planning of the access. The approximated average effective dose of 0.85 ± 0.48 mSv (range: 0.34 – 1.93 mSv) in this patient group was significantly higher than in the subgroup without such a planning scan (t-test, p < 0.001). With an average time of 20.7 minutes, the intervention duration was not significantly higher than in the patient group without a necessary planning scan.

According to the wage contracts for physicians and civil service employees at German university hospitals, the personnel costs per minute were EUR 0.77 for the treating radiologist and EUR 0.35 for the X-ray assistant. Under consideration of the involvement times for physicians and X-ray assistants in both intervention types, the personnel costs were EUR 46.04 for an MRI-guided intervention and EUR 39.64 for a CT-guided intervention (Table 2). Costs of EUR 43.74 for MRI guidance and EUR 24.83 for CT guidance or sonographic guidance were calculated for disposables (Table 1). The equipment usage costs were EUR 149.65 per patient for each MRI-guided intervention and

<table>
<thead>
<tr>
<th>type of material</th>
<th>manufacturer</th>
<th>price (in EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20G MRI-compatible puncture</td>
<td>Needle Chiba MREye® Access, Cook</td>
<td>25.60</td>
</tr>
<tr>
<td>needle, 90 mm</td>
<td>Medical, Limerick, Ireland</td>
<td></td>
</tr>
<tr>
<td>40 mg triamcinolone acetone</td>
<td>Winthrop Arzneimittel GmbH,</td>
<td>3.04</td>
</tr>
<tr>
<td>(Triam®)</td>
<td>Mühlheim, Germany</td>
<td></td>
</tr>
<tr>
<td>Carbozestin® 0.5 %</td>
<td>AstraZeneca, Wedel, Germany</td>
<td>1.40</td>
</tr>
<tr>
<td>(bupivacaine hydrochloride)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local anesthetic</td>
<td>AstraZeneca, Wedel, Germany</td>
<td>1.56</td>
</tr>
<tr>
<td>XyloNest® 1 % (Lidocaine + 1 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adrenaline)</td>
<td>basic set for punctures,</td>
<td>7.88</td>
</tr>
<tr>
<td></td>
<td>B. Braun, Melsungen, Germany</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Becton Dickinson SA, S. Agustin del</td>
<td>3.13</td>
</tr>
<tr>
<td></td>
<td>Gualdix, Spain</td>
<td></td>
</tr>
<tr>
<td>sterile surgical drape with</td>
<td>Lohmann &amp; Rauscher International,</td>
<td>1.10</td>
</tr>
<tr>
<td>hole</td>
<td>Rengsdorf, Germany</td>
<td></td>
</tr>
<tr>
<td>sterile drape 50 × 60 cm</td>
<td>Lohmann &amp; Rauscher International,</td>
<td>1.68</td>
</tr>
<tr>
<td></td>
<td>Rengsdorf, Germany</td>
<td></td>
</tr>
<tr>
<td>sterile gloves</td>
<td>Ansell GmbH, Munich, Germany</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td>Sterile gloves</td>
<td>1.48</td>
</tr>
<tr>
<td>total cost of disposables</td>
<td>EUR 149.65 per patient for each</td>
<td></td>
</tr>
<tr>
<td>for MRI-guided intervention (in</td>
<td>MRI-guided intervention and</td>
<td></td>
</tr>
<tr>
<td>EUR)</td>
<td>sonographic guidance were calculated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for disposables (Table 1).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EUR 24.83</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Costs of disposables used in CT-guided and MRI-guided cervical nerve root infiltration. The cost of disposables for ultrasound guidance was the same as for CT fluoroscopic guidance.

Tab. 1 Kosten für das Verbrauchsmaterial bei MRT- und CT-gesteuerten cervicalen Nervenwurzelninfiltrationen. Die Materialkosten bei sonografischer Steuerung entsprachen denjenigen der CT-fluoroskopischen Steuerung.
Table 2  Process steps and personnel costs of CT-guided and MRI-guided nerve root infiltration.

Tab. 2 Prozessschritte und Personalkosten der CT- und MRT-gesteuerten Nervenwurzelinfiltrationstherapien.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Code (costs per minute)</th>
<th>Minutes</th>
<th>Total</th>
<th>Cost code (costs per minute)</th>
<th>Minutes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preparation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient registration</td>
<td>technician (0.35)</td>
<td>3</td>
<td>1.05</td>
<td>Patient registration</td>
<td>technician (0.35)</td>
<td>3</td>
</tr>
<tr>
<td>Informational discussion</td>
<td>physician (0.77)</td>
<td>5</td>
<td>3.85</td>
<td>Informational discussion</td>
<td>physician (0.77)</td>
<td>5</td>
</tr>
<tr>
<td>Preparation of materials and</td>
<td>technician (0.35)</td>
<td>5</td>
<td>1.75</td>
<td>Preparation of materials and</td>
<td>technician (0.35)</td>
<td>5</td>
</tr>
<tr>
<td>equipment</td>
<td></td>
<td></td>
<td></td>
<td>equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positioning of the patient</td>
<td>technician (0.35)</td>
<td>3</td>
<td>1.05</td>
<td>Positioning of the patient</td>
<td>technician (0.35)</td>
<td>5</td>
</tr>
<tr>
<td>Sterile drape</td>
<td>physician (0.77)</td>
<td>2</td>
<td>1.54</td>
<td>Sterile drape</td>
<td>physician (0.77)</td>
<td>2</td>
</tr>
<tr>
<td>Preparation of injectate</td>
<td>physician (0.77)</td>
<td>2</td>
<td>1.54</td>
<td>Preparation of injectate</td>
<td>physician (0.77)</td>
<td>2</td>
</tr>
<tr>
<td>technician (0.35)</td>
<td>2</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT scout, localization imaging</td>
<td>physician (0.77)</td>
<td>19.7</td>
<td>15.17</td>
<td>MRI scout, setting of the</td>
<td>physician (0.77)</td>
<td>24.9</td>
</tr>
<tr>
<td>(single scans or short CT spiral)</td>
<td>technician (0.35)</td>
<td>19.7</td>
<td>6.90</td>
<td>interactive sequence1,</td>
<td>technician (0.35)</td>
<td>24.9</td>
</tr>
<tr>
<td>Local anesthesia, CT-guided</td>
<td></td>
<td></td>
<td></td>
<td>localization of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>advancement of the injection</td>
<td></td>
<td></td>
<td></td>
<td>target region, local</td>
<td></td>
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<td>cannula, administration of the</td>
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<td></td>
<td>anesthesia, MRI-guided</td>
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<tr>
<td>injectate, control imaging of</td>
<td></td>
<td></td>
<td></td>
<td>advancement of the</td>
<td></td>
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<tr>
<td>contrast agent distribution</td>
<td></td>
<td></td>
<td></td>
<td>injection cannula,</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>administration of the</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>injectate, postinterventional imaging</td>
<td></td>
<td></td>
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<tr>
<td>Postinterventional activities</td>
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</tr>
<tr>
<td>Helping the patient up</td>
<td>technician (0.35)</td>
<td>2</td>
<td>0.7</td>
<td>Helping the patient up</td>
<td>technician (0.35)</td>
<td>2</td>
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<td>Final discussion</td>
<td>physician (0.77)</td>
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<td>1.54</td>
<td>Final discussion</td>
<td>physician (0.77)</td>
<td>2</td>
</tr>
<tr>
<td>Reporting</td>
<td>physician (0.77)</td>
<td>5</td>
<td>3.85</td>
<td>Reporting</td>
<td>physician (0.77)</td>
<td>5</td>
</tr>
<tr>
<td>Total personnel costs for CT-guided ed periradicular pain therapy</td>
<td>39.64</td>
<td>39.64</td>
<td>46.06</td>
<td>Total personnel costs for MRI-guided periradicular pain therapy</td>
<td>46.06</td>
<td>46.06</td>
</tr>
</tbody>
</table>

1 Optional diagnostic MRI examination of the cervical spine. For ultrasound-guided interventions, a mean intervention time of 20 minutes was assumed. The pre- and post-intervention time requirement was the same as for CT-guided interventions: 15 minutes for the technician and 16 minutes for the radiologist. Overall, the mean personnel costs were 39.97 EUR per ultrasound-guided intervention.

Table 3  Costs of equipment use per intervention assuming 7-year depreciation.

Tab. 3 Gerätenutzungskosten je Intervention unter der Annahme einer 7-jährigen Nutzungsdauer der verwendeten Geräte.

<table>
<thead>
<tr>
<th>Cost type of equipment costs (in EUR)</th>
<th>CT Siemens Definition 64</th>
<th>open MRI system Philips 1.0 T Panorama HFO</th>
<th>ultrasound unit Acuson Antares S2000, Siemens Healthcare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing costs</td>
<td>670 000</td>
<td>1 250 000(^1)</td>
<td>129 000</td>
</tr>
<tr>
<td>Annual maintenance costs</td>
<td>45 000</td>
<td>60 000(^1)</td>
<td>4 000</td>
</tr>
<tr>
<td>Annual usage duration (in minutes)</td>
<td>90 000</td>
<td>24 000(^1)</td>
<td>72 000</td>
</tr>
<tr>
<td>Energy costs per minute of usage (in EUR)</td>
<td>0.20</td>
<td>0.34</td>
<td>0.03</td>
</tr>
<tr>
<td>Costs per minute (in EUR)</td>
<td>1.56</td>
<td>3.31(^1)</td>
<td>0.31</td>
</tr>
<tr>
<td>Average duration of an intervention (in minutes)</td>
<td>34</td>
<td>41(^1)</td>
<td>34(^2)</td>
</tr>
<tr>
<td>Total equipment usage costs per intervention (in EUR)</td>
<td>59.84</td>
<td>149.65(^1)</td>
<td>11.56</td>
</tr>
</tbody>
</table>

\(^1\) Used by different departments with use by the radiological department accounting for only about one third of total use; maintenance costs were taken into account proportionately. The lengths of time given are procedure room usage times (rounded to the minute).

\(^2\) The mean intervention time for an ultrasound-guided intervention was subject to an estimate.

Fig. 3  Distribution of cervical spinal segments treated using MRI and CT guidance in both patient groups.

Abb. 3 Verteilung der mittels CT- und MRT-gesteuerter Infiltrationstherapie behandelten zervikalen Nervenwurzeln in den einbezogenen Patientenkollektiven.
EUR 59.84 per patient when using CT guidance (Table 3). The average total cost per patient was EUR 239.45 for an MRI fluoroscopy-guided nerve root infiltration and EUR 124.31 for a CT fluoroscopy-guided nerve root infiltration (Table 4). The sonographic guidance data were estimates. The material costs for the sonographically controlled intervention corresponded to those of the CT-guided intervention.

Discussion

Periradicular nerve root infiltration under fluoroscopic, CT fluoroscopic, and sonographic guidance has proven to be a safe and effective therapy method for treating patients in whom conservative treatment of cervical discomfort and cervical radicular pain syndrome is not sufficient [4, 32–34]. Therapy guidance via MRI was also able to be subsequently clinically established [22, 35]. In our study, the technical success rate was 100%. Treatment with periradicular injectate distribution was able to be properly performed in all patients in both groups.

However, a cost comparison showed that the costs for MRI-guided treatment (EUR 240) were on average 1.92 times higher than the costs for CT guidance (EUR 124). The substantially higher equipment usage costs for the MRI scanner (EUR 150 vs. 60, factor 2.50) due to the substantially higher purchasing and maintenance costs for the open 1.0-Tesla MRI system contributed significantly to this. There is potential to further reduce the fixed costs per intervention, e.g., by increasing the number of treatments or by sharing equipment usage with other departments, such as the orthopedic department in our hospital and with research groups. Alanen et al. [26] compared the costs for bone biopsies under CT guidance and MRI guidance using a 0.23-Tesla low-field MRI system. The authors calculated only 1.82 times higher average equipment usage costs for MRI-guided interventions compared to CT guidance. Low-field MRI systems could also be used for MRI-guided cervical nerve root infiltration and could significantly lower the proportionate equipment usage costs [36, 37]. Compared to the use of CT and MRI for treatment guidance, the very low equipment usage costs for ultrasound units (EUR 12, factor 0.19 compared to CT equipment usage costs and factor 0.08 compared to MRI equipment usage costs) contribute greatly to the fact that ultrasound is by far the most cost-effective method.

The average costs per patient for disposables under MRI guidance were 1.76 times higher than the same costs under CT guidance in our study. Alanen et al. [26] found significantly greater differences in a cost comparison of CT-guided and MRI-guided bone biopsies with 5.57 times higher costs for MRI-compatible disposables. Primarily the cost of MRI-compatible injection cannulas is currently still several times higher (EUR 25 vs. 3, factor 8.2, Table 1) than that of conventional cannulas that can be used for CT guidance. Although significant price reductions for MRI-compatible injection cannulas due to declining production costs and an increase in demand and production have been seen in recent years (cost per cannula in 2004 was approx. EUR 100), further potential for price reductions and greater comparability in the price of CT and MRI-compatible injection cannulas should be able to be expected given the increasing demand. A further reason for the higher average total costs of MRI-guided interventions was the higher personnel costs (MRI/CT guidance EUR 44 vs. 25, factor 1.8). The cost difference was due to the slightly longer average intervention time for MRI-guided interventions (MRI 24.9 minutes vs. CT 19.7 minutes). To date the literature only contains intervention times for CT and MRI-guided nerve root infiltration therapies for the lumbar spine. Therefore, Sequeiros et al. [21] documented an average process time of 33 minutes (range: 9–84 minutes) for MRI-guided interventions, Ojala et al. [35] recorded a time of 32 minutes (range: 12–62 minutes), Fritz et al. [22] documented an average time of 42 minutes (range: 23–75 minutes) and Streitparth et al. [20] recorded a time of 27 minutes (range: 19–67 minutes). The average intervention time for MRI-guided cervical infiltrations of 24.9 minutes was less than the times in these studies. This is surprising in that a tendency toward a longer intervention time for the cervical spine can be assumed since the access for this intervention is often more difficult under consideration of the cervical risk structures [38]. Finally the duration of the intervention also depends on the experience of the interventionalist [20]. Therefore, the average intervention duration for the first five patients in a patient collective of Ojala et al. [35] was 34 minutes, while the average time for the last five patients was only 23 minutes. Two radiologists with MRI-guided intervention experience performed the infiltrations in our study. A learning curve was seen with an average intervention duration of 28.2 minutes for the first five patients and 19.2 minutes for the last five patients.

In addition to the examined costs, the lack of radiation exposure is an advantage of MRI-guided therapy guidance and sonographic guidance. The radiation exposure needed for CT fluoroscopic guidance has a potentially damaging effect on patients and personnel [15–17] and is of importance because many patients often require multiple interventions to achieve lasting pain relief. Hoang et al. [39] and Schmid et al. [40] documented the average effective dose in CT-guided nerve root infiltrations with the help of a phantom model and calculated average effective dose values of 0.45 mSv and between 0.22 – 0.45 mSv. A similar average dose value of 0.48 mSv (approximated) was achieved in our study. However, the increase in effective dose caused by the need for a spiral CT scan for better localization of the cervical nerve root and planning of the access was lower for the cervical spine than for the lumbar spine. Although such a scan was necessary in 17 of 64 cases in our study and the average effective dose of 0.85 mSv was significantly higher, the increase in the study of Hoang et al. [39] was up to 2.9 mSv for the lumbar spine. Since MRI-guided nerve root infiltration does not require radiation exposure for patients and personnel, it should be used primarily in patients with...
expected severe degenerative changes of the cervical spine, in
the case of an anticipated serial therapy regimen, and in younger
patients. In addition to multiplanar navigation options, MRI
fluoroscopy allows precise and reliable positioning of the injec-
tion cannula and, due to the excellent soft tissue contrast, does
not require iodine-containing contrast agents with a potential al-
lergoid effect. Sonographic treatment guidance has become es-
dablished as an alternative method that also does not require ra-
diation exposure or contrast agents. Like MRI compared to CT
fluoroscopy, this allows significantly better soft tissue contrast
and precise visualization of sensitive structures like the vertebral
artery and is primarily suitable for injections in the lower cervical
spine segments [41, 42]. Exact guidance and localization of the
injection cannula increases the safety for the patient. Although
rare, complications such as dissection of the vertebral artery, ir-
reversible nerve damage and spinal, cerebellar, or cerebral infarc-
tions have been described in connection with periradicular cervi-
cal injections [11, 43]. The interactive PDw FSE sequence that we
used allowed guidance and localization of the needle tip with
precision comparable to that of CT fluoroscopy [20, 44].
With respect to possible complications, the use of crystalloid and
non-crystallloid corticosteroids has been controversial even
though there is apparently no major difference in medical effec-
tiveness [45]. It was assumed that complications are based on an
embolic mechanism in the case of accidental injection, e.g. into a
radicular artery, and corticosteroids with a clumping tendency
could have a less favorable risk profile in this context [46]. Tiso
et al. [47] therefore recommended using non-crystallloid corti-
costeroids for pain therapy in the cervical spine. However, in a
large patient collective of 4612 patients treated within a period
of 13 years, Schellhas et al. were not able to identify an increased
incidence of complications when using crystalloid cortisoste-
roids [32].
A limitation of our study is that the cost evaluation was limited to
cost types that could be directly allocated to individual interven-
tions from the viewpoint of a radiological department. There are
certainly numerous additional costs, e.g. construction costs,
cleaning costs, and data storage costs. Since these cost types
could not be definitively allocated to a real patient collective,
they were not included. However, energy costs that could be cal-
culated and directly allocated to an intervention were taken into
consideration. Moreover, the alternative method of fluoroscopic
therapy guidance was not taken into consideration in our cost a-
nalysis. The discussion regarding costs is a current topic particu-
larly with respect to the changes in reimbursement by statutory
health insurance funds of 4/1/2013 [48]. Moreover, radiological
service providers are increasingly required to bring their own
services strictly in line with economic criteria and achievable rev-
ues. System utilization optimization and revenue per time unit
are important in this regard. MRI fluoroscopy-guided pain ther-
apy at institutions with little experience in this area may initially
have an unfavorable time-revenue ratio. However, a high learning
curve and significant reduction in the time requirement can soon
be expected.

**Conclusion**

Cervical nerve root infiltration under MRI guidance is currently
approximately twice as expensive per patient compared to infil-
tration therapy under CT fluoroscopy guidance. In the case of ex-
pected additional price reductions for MRI-compatible injection
cannulas and possible usage of low-field scanners or convention-
al tunnel systems, MRI-guided nerve root infiltration seems to be a
promising alternative to previously established CT fluoroscopic
methods under consideration of the lack of radiation exposure for
patients and personnel. However, ultrasound-guided therapy
continues to be the most cost-effective method.

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