Journal of Pain Research Dovepress

Open Access Full Text Article ORIGINAL RESEARCH

Real-Time Ultrasound-Guided CT-Monitored Percutaneous Cervical Disc Injection: An Emerging Approach for Accurate Diagnosis of Cervical Discogenic Diseases

Haimiti Abudouaini[1], Junsong Yang[1], Meng Li[2], Pingzheng Zhang[2], Kaiyuan Lin[1], Yonghong Jiang[3], Kongjiang Tao[3], Hong Zhang[2]

[1]Department of Spine Surgery, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi, 710054, People's Republic of China; [2]Department of Ultrasound Medical Center, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi, 710054, People's Republic of China; [3]Department of Computed Tomography, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi, 710054, People's Republic of China

Correspondence: Hong Zhang, Department of Ultrasound Medical Center, Honghui Hospital, Xi'an Jiaotong University, No. 76, Nanguo Road, Beilin District, Xi'an, Shaanxi, 710054, People's Republic of China, Email 254972342@qq.com

Objective: To explore the preliminary application value of real-time ultrasound-guided combined with CT monitoring in percutaneous cervical disc puncture injection for diagnostic trials.

Methods: Sixty patients with suspected cervical discogenic dizziness undergoing percutaneous cervical disc puncture between January 2023 and February 2024 were randomly divided into two groups: real-time ultrasound-guided combined with CT monitoring and CT-guided alone. The groups were compared for pre-puncture positioning time, total puncture process time, number of CT exposures, and complications. Subsequent treatment and medications were consistent between the two groups.

Results: Sixty patients were divided into the the real-time US-guided combined with CT monitoring group (n=30) and the CT-guided group (n=30). Pre-puncture positioning time in the real-time US-guided combined with CT monitoring group was shorter than that in the CT-guided group, but there was no statistical difference between the two groups ($P>0.05$). The total puncture process time and the number of CT exposures in the real-time US-guided combined with CT monitoring group were smaller than those in the CT-guided group, and there was a statistical difference between the two groups ($P<0.05$). Two cases of hematoma appeared in CT guidance alone, and no hematoma appeared in the real-time US-guided combined with CT monitoring group.

Conclusion: Real-time ultrasound-guided combined with computed tomography monitoring in percutaneous cervical disc puncture is a rapid, visible, safe, and effective method.

Keywords: real-time ultrasound guidance, CT guidance, cervical disc puncture diagnostic trial, cervical discogenic dizziness, cervical spine disease

Introduction

Cervical spondylosis is a common chronic disease, manifesting primarily as chronic or persistent neck pain and intractable dizziness, posing a significant impact on patients' work and daily life. When ruling out dizziness caused by otolaryngological or neurological disorders, dizziness arising from degeneration of the cervical intervertebral discs is referred to as cervical discogenic dizziness.[1,2] Although the specific mechanisms underlying cervical discogenic dizziness remain unclear, recent studies have confirmed a potential association with the abnormal elongation of Ruffini corpuscles into degenerated intervertebral discs.[3] There are both nerve terminals and mechanoreceptors in the cervical disc.[4] The main role of the Ruffini corpuscles in normal disc is to maintain muscle tone, monitor position, speed and movement, and deliver proprioception to the central nervous system. During disc degeneration, the level of inflammatory factors

Received: 26 May 2024
Accepted: 13 November 2024
Published: 23 November 2024

increases, and free nerve endings and Ruffini bodies are sensitive, leading to abnormal proprioceptive afferent nerves, resulting in feelings of pain or dizziness and instability.[5]

The main symptoms of cervical pain and dizziness can be diagnosed and localized through diagnostic intra-discal injection tests, particularly for identifying the responsible intervertebral disc.[6,7] Bupivacaine Can inhibit the sodium ion channel of nerve cells, make nerve cells lose excitability and conductivity, can effectively block the transmission of pain signals, it has been proved that[8] can relieve the symptoms of neck pain and dizziness. For patients with a confirmed diagnosis and accurate localization of cervical discogenic dizziness, surgical intervention has proven to be an effective method for alleviating symptoms.[7]

In the past, diagnostic intra-discal injection tests for cervical discogenic dizziness were typically conducted under radiographic guidance. However, with the maturation of ultrasound-guided puncture techniques, ultrasound guidance has gradually replaced traditional radiographic guidance. Ultrasound guidance offers advantages such as radiation-free procedures, safety, and cost-effectiveness, and it has been widely applied in puncture injections for cervical nerve root blockade and cervical facet joints.[9,10] While ultrasound-guided puncture techniques have achieved success in various fields, their application in diagnostic intra-discal injections for cervical discogenic dizziness has not been thoroughly investigated. Therefore, the aim of this study is to explore the preliminary application value of real-time ultrasound guidance combined with CT monitoring in percutaneous cervical intervertebral disc puncture diagnostic injection tests and provide new perspectives and methodologies for studies in this field.

Methods and Materials

Study Population

Patients with suspected degenerative cervical disc-related neck pain and dizziness treated at spine surgery in our hospital from January 2023 to February 2024 were included. Inclusion criteria were as follows: (1) Chronic or persistent neck pain and refractory dizziness with no response to conservative treatment for at least one year, with or without other symptoms such as headache, visual disturbances, nausea, or tinnitus. (2) Cervical magnetic resonance imaging (MRI) showing degenerative changes in the C3-C7 cervical discs without compression of nerve roots or the cervical cord. (3) Willingness to participate in the study and signing of informed consent. (4) Patients with no allergic reaction to lidocaine. Exclusion criteria included: (1) Presence of cervical disc protrusion on imaging, nerve root or spinal cord compression, or ossification of the posterior longitudinal ligament (OPLL). (2) Inability to rule out specialty-related diseases such as benign paroxysmal positional vertigo (BPPV), neurogenic functional syndrome, or Meniere's syndrome by otolaryngology or neurology. (3) Presence of cervical tumor or local skin infection. (4) History of cervical spine fracture or surgery. (5) Psychiatric disorders. (6) Central nervous system diseases, such as Alzheimer's disease, cerebral infarction, cerebral hemorrhage, epilepsy, etc. (7) Pregnant females.

A total of 60 patients were selected based on the affected disc level indicated by patient lesions and MRI findings. The segments chosen for diagnostic treatment were C4-5, C5-6, and C6-7, with 10 cases involving C4-5, 44 cases involving C5-6, and 6 cases involving C6-7. The patients included 32 males and 28 females, with an age range of 26–67 years and a mean age of 47 years. US-guided combined with CT monitoring group (n=30), age (55.8±9.8) years, male to female 13:17, CT-guided group (n=30), age (58.6 ±6.9) years, male to female 15:15. The study was in accordance with the Declaration of Helsinki, and all subjects had signed an informed consent form. The study was approved by the Ethics Committee of Honghui Hospital, Xi'an Jiaotong University, under the approval number: 202401019.

Injection Medication

For suspected degenerative cervical disc diagnostic injections, the injection medication used was 0.25% bupivacaine (0.3–0.5 mL).

Instruments and Procedures

i) Instruments: The Siemens ACUSON Sequoia color Doppler ultrasound diagnostic instrument with a probe frequency of 10L4 MHz, a United Imaging CT machine, and a Lepu PTC puncture needle (18G) were used; ii) Procedures: Patients

were randomly divided into two groups. In the first group, real-time ultrasound guidance combined with CT monitoring was performed by a radiologist. The patients were placed in a supine position, with the head slightly tilted to the left for optimal exposure of the right neck. The ultrasound probe was positioned beside the sternocleidomastoid muscle for transverse scanning. Under ultrasound guidance, the C6 transverse process was initially located, followed by fine adjustments to identify the C6-7 intervertebral disc. The probe was further adjusted to locate the C5-6 intervertebral disc. The needle entry point was marked on the skin surface using a pen, and the time for pre-puncture ultrasound targeting was recorded. After routine disinfection and local anesthesia with 2% lidocaine (2–3 mL), the ultrasound probe, covered with a sterile sheath, was used for real-time guidance. The puncture needle (18G, 10 cm) was slowly advanced to the edge of the target intervertebral disc under ultrasound guidance (Figure 1A). CT scanning was performed to confirm the needle tip reaching the edge of the target intervertebral disc (Figure 2). The needle was then further advanced into the

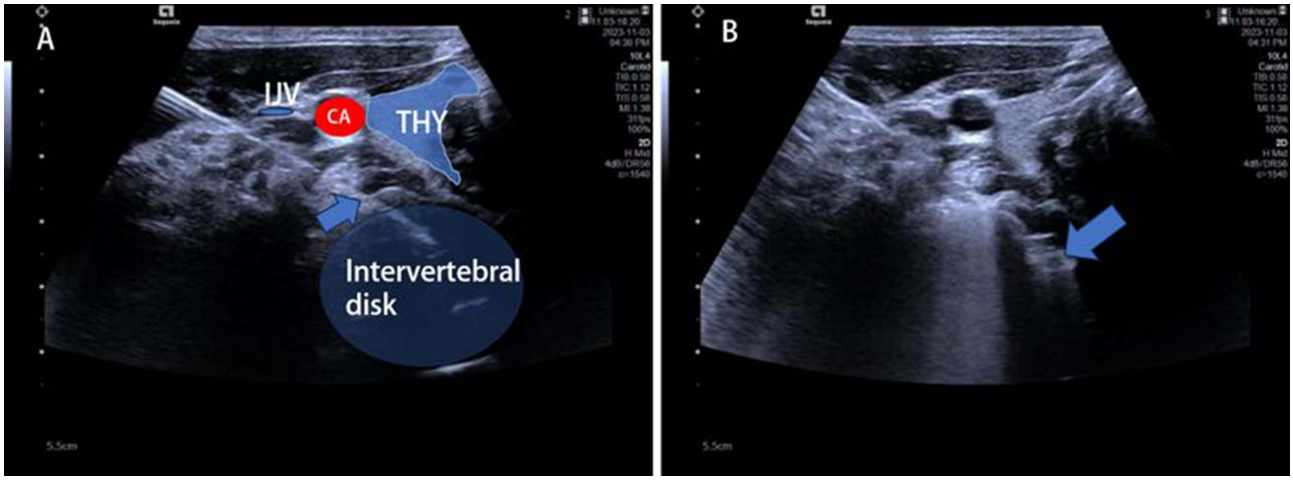

Figure 1 The process of the real-time ultrasound-guided CT-monitored percutaneous. (**A**) The needle is inserted into the C5-6 intervertebral disc (arrow indicates the needle tip, elliptical circle highlights the hypoechoic disc); (**B**) Ultrasound clearly demonstrates the drug injected into the C5-6 intervertebral disc (arrow indicates the hyperechoic drug).

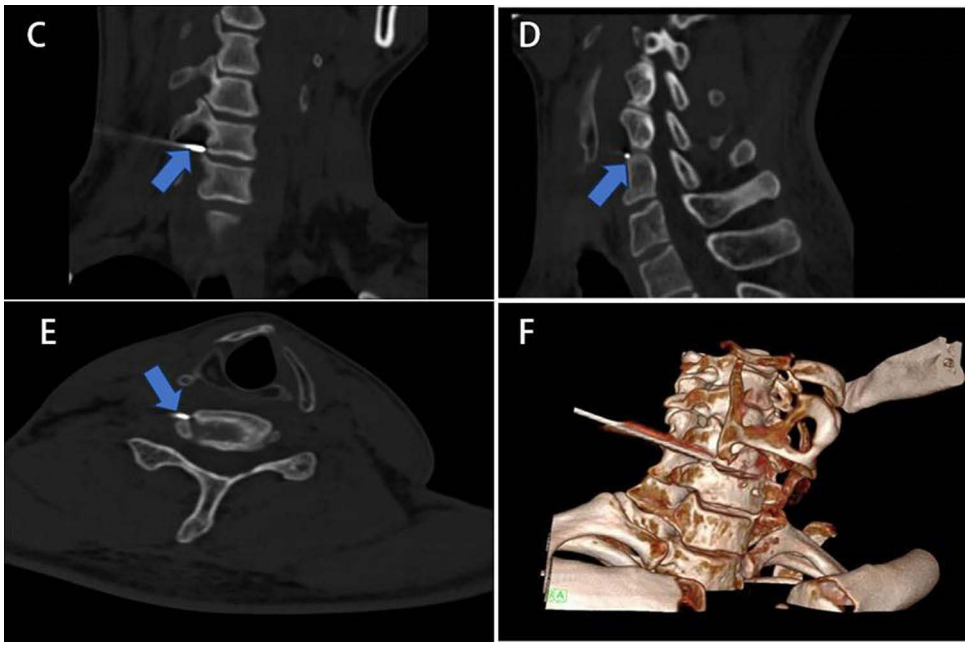

Figure 2 The process of CT-monitored: Arrow shows the puncture tip reaching the edge of the C5-6. ((**C**) coronal plane (**D**) sagittal plane (**E**) transverse plane (**F**) three-dimensional reconstruction).

intervertebral disc under ultrasound guidance, and another CT scan was conducted to confirm the needle tip within the target intervertebral disc (Figure 3). The total time of the puncture process (from the start of needle insertion to the placement of the needle) and the number of CT exposures were recorded. Following successful puncture, subsequent drug administration and observation were conducted by a spine surgeon, with treatment methods and drugs identical in both groups. The drug dispersion within the intervertebral disc could be observed using ultrasound during drug administration (Figure 1B).

In the regularly CT-guided group, a spine surgeon performed a single CT-guided puncture. Patients were placed in a supine position with a slight extension of the neck. After surface localization using a 7-gauge needle and CT irradiation to determine the puncture plane, the puncture point was anesthetized with 2% lidocaine (2–3 mL). The surgeon used the thumb to palpate the internal edge of the sternocleidomastoid muscle in the corresponding plane and pushed the common carotid artery outward by 1.0–1.5 cm. This maneuver aimed to position the common carotid artery on the thumb side while pressing the vertebral body simultaneously to widen the space between the carotid sheath and the trachea or esophagus. The needle was inserted from the backside of the surgeon's thumb, obliquely from the junction of the anterior and lateral edges of the intervertebral.

Statistical Analysis

The retrospective nature of the study predetermined the fixed sample size based on the available data, and no power calculation for sample size was conducted upfront. Statistical analysis was performed using SPSS version 26.0. Quantitative data consistent to normal distribution were expressed as mean (x) ± standard deviation (s), Qualitative data expressed as percentage (%). The independent sample *t*-test was utilized to assess differences in pre-puncture localization time, total puncture process time, and the number of CT monitoring exposures between the two groups. The $\chi 2$ test or Fisher's exact probability method was used to compare the quantitative data. Statistical significance was considered at $P < 0.05$.

Results

Patient Demographic Data

All 60 patients successfully completed the puncture procedure. CT monitoring confirmed that the puncture needles in all patients reached the intended intervertebral disc position, and injection of bupivacaine (0.25%, 0.3~0.5 mL) was

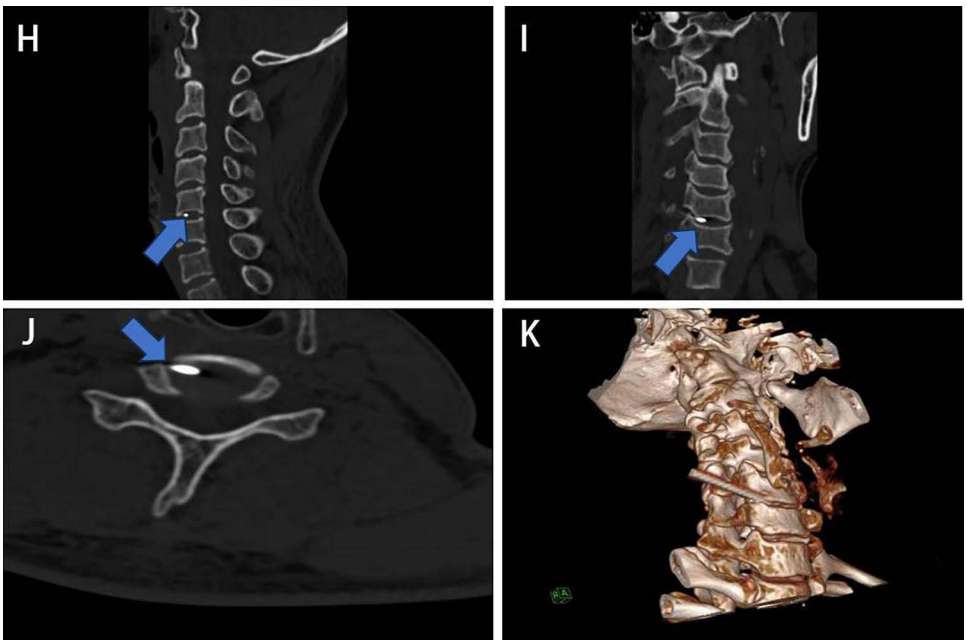

Figure 3 The process of CT-monitored: Arrow shows the puncture needle tip reaching the C5-6 intervertebral disc ((**H**) coronal plane (**I**) sagittal plane (**J**) transverse plane (**K**) three-dimensional) reconstruction.

performed for disc block testing. There was no statistically significant difference in age, heart rate, body mass index, gender, and blood pressure between US-guided combined with CT monitoring group and CT-guided group. The results of the study were summarized as follows (P all > 0.05, shown in Table 1).

Comparison of Percutaneous Cervical Disc Puncture Injection Diagnostic Trials Related Parameters

In the real-time ultrasound-guided combined with CT monitoring group, the pre-puncture localization time ranged from 3 to 6 minutes, with an average of (3.8±1.0) minutes. For the CT-guided group, the pre-puncture localization time varied from 4 to 8 minutes, averaging (5.3±1.1) minutes. The difference in pre-puncture localization time between the two groups was not statistically significant (t=5.755, p>0.05). The total puncture process time for the real-time ultrasound-guided combined with CT monitoring group ranged from 8 to 13 minutes, with an average of (9.6±1.4) minutes. In the CT-guided group, the total puncture process time varied from 9 to 24 minutes, averaging (15.6±3.2) minutes. The difference in total puncture process time between the two groups was statistically significant (t=9.350, p<0.05). The number of CT exposures in the real-time ultrasound-guided combined with CT monitoring group ranged from 2 to 4 times, with an average of (2.4±0.6) times. In the CT-guided group, the number of CT exposures ranged from 4 to 8 times, averaging (5.4±1.1) times. The difference in the number of CT exposures between the two groups was statistically significant (t=13.902, p<0.05). Regarding complications, two cases of hematoma occurred in the CT-guided group, while no significant complications were observed in the real-time ultrasound-guided combined with CT monitoring group (Shown in Table 2).

Table 1 Baseline Characteristics of the Study Populations $(\bar{X} \pm s)$

Baseline Characteristics	US-Guided Combined with CT Monitoring Group (n=30)	CT-Guided Group (n=30)	*P* valves
Age, years	55.8±9.8	58.6±6.9	0.146
Heart rate (bpm)	72.6±8.3	72.9±7.5	0.555
BMI (kg/m^2)	23.3±2.9	24.0±3.5	0.314
Gender (F:M)	17:13	15:15	0.605
SBP (mmHg)	121.2±11.2	121.8±10.4	0.884
DBP (mmHg)	74.4±10.6	75.2±9.1	0.138

Abbreviations: BMI, body mass index; HR, heart rate; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.

Table 2 Comparison of Percutaneous Cervical Disc Puncture Injection Diagnostic Trials Related Parameters Between the 2 Groups $(\bar{X} \pm \mathrm{S})$

Variables	US-Guided Combined with CT Monitoring Group (n=30)	CT-Guided Group (n=30)	95% CI (Upper-Lower)	*P* values
The pre-puncture localization time (min)	3.8±1.0	5.3±1.1	(−0.98~-2.02)	0.749
The total puncture process time (min)	9.6±1.4	15.6±3.2	(−4.65~-7.22)	**0.016**
The number of CT exposures (times)	2.4±0.6	5.4±1.1	(−2.63~-3.51)	**0.006**
Complications (hematoma)	0(0%)	2(7%)	/	<0.001

Note: Bold font indicates that P < 0.05.

Discussion

Cervical discogenic dizziness refers to dizziness caused by degeneration of the cervical intervertebral disc, clinically characterized by predominant symptoms of neck pain and dizziness.[11–13] In some patients, magnetic resonance imaging reveals degeneration of the cervical intervertebral disc without disc protrusion or compression of nerve roots and the spinal cord.[14] The diagnosis of cervical discogenic dizziness requires excluding dizziness caused by neurological, otolaryngological, and other diseases. Studies suggest that the pathogenesis of cervical discogenic dizziness involves excessive activation of Ruffini corpuscles within the cervical intervertebral disc, leading to abnormal proprioceptive signals transmitted to the vestibular nucleus, resulting in vestibular dysfunction and subsequent dizziness.[3,15,16] Diagnostic tests, such as intradiscal block tests conducted by Yang et al[7] play a crucial role in identifying the responsible intervertebral disc. In cases where local anesthetic injection relieves dizziness immediately and lasts for several hours, subsequent anterior cervical surgery has been shown to provide sustained relief.[15,17–19]

Therefore, preoperative percutaneous suspected cervical intervertebral disc injection can serve both diagnostic and therapeutic purposes for patients with cervical discogenic dizziness, guiding subsequent clinical interventions. With the increasing application of minimally invasive techniques in cervical spine procedures and the widespread adoption of precision medicine, accurate preoperative localization of cervical discogenic dizziness patients becomes increasingly crucial. However, the cervical intervertebral disc is smaller than the lumbar intervertebral disc, and the cervical cord is a high-risk area with numerous vital structures such as nerves, vertebral arteries, jugular veins, esophagus, and trachea. Moreover, the vascular variations around the cervical intervertebral foramina are considerable,[20] and any incorrect injection or injury can have severe consequences. Therefore, achieving precise, effective, and safe puncture to the target intervertebral disc is of paramount importance.

Traditionally, cervical intervertebral disc puncture under imaging guidance is primarily performed under fluoroscopy.[21,22] In recent years, many studies[23] have reported and advocated for cervical puncture under CT guidance, leveraging CT's ability to visualize major vessels and other anatomical structures in the neck and perform three-dimensional reconstructions after scanning, thereby enhancing accuracy and safety. However, CT guidance has limitations, including high costs and significant radiation exposure. Ultrasound-guided interventions offer unique advantages, such as clear visualization of soft tissues, including muscles, nerves, and blood vessels; real-time display of needle tip position in relation to the target; and reduced radiation exposure for patients and medical staff.[24,25] Clinical practice and related literature indicate a growing trend in the widespread application of ultrasound-guided minimally invasive interventions in the diagnosis and treatment of spinal pain,[26] including procedures like cervical nerve root block and facet joint injections.[10] Although the imaging of cervical intervertebral discs under ultrasound is limited due to the influence of cervical vertebral bone, the CT can accurately show the vertebral bone.[27] If the advantages of real-time ultrasound imaging, radiation-free nature, and clear CT display of the cervical intervertebral disc could be combined, the optimal guidance effect would be achieved. Wakeling et al[25] used a combination of two techniques for selective cervical nerve root block, using ultrasound dynamic guidance during puncture to avoid vascular and nerve structures and utilizing X-ray to prevent vascular incorrect injection. This approach reduced complications while minimizing exposure time during the procedure. However, there is currently no literature reporting the application of real-time ultrasound guidance combined with CT monitoring in percutaneous cervical intervertebral disc injection for diagnostic and therapeutic purposes.

In this study, the Siemens ACUSON Sequoia color Doppler ultrasound diagnostic instrument was employed for pre-procedural ultrasound localization of the cervical intervertebral disc plane. The entire procedure was visualized under ultrasound guidance, allowing real-time monitoring of the needle tip and its trajectory. Upon reaching the right anterior margin of the target intervertebral disc, confirmation of the target's accuracy was performed under CT guidance before advancing the puncture needle into the target intervertebral disc. Subsequent to confirming the needle's entry into the intervertebral disc via CT, the dispersion of medication within the disc was observed under ultrasound guidance. The integration of real-time ultrasound imaging, radiation-free characteristics, and clear visualization of neck structures, coupled with the sharp imaging of cervical vertebrae and intervertebral discs in CT images, facilitated precise targeting of

the intervertebral disc. This approach overcame the limitations of sole CT guidance, which lacks real-time visualization of neck vessels and nerves.

Comparison between the two groups revealed a lower number of CT surveillance exposures in the real-time ultrasound-guided combined with CT monitoring group compared to the sole CT-guided group. The former only required CT surveillance during the advancement of the puncture needle to the right anterior margin of the target intervertebral disc and when the needle entered the intervertebral disc. In contrast, the sole CT-guided group needed CT surveillance exposures before puncture positioning, during puncture, reaching the right anterior margin of the target intervertebral disc, and when the needle entered the intervertebral disc. The reduction in the number of CT exposures significantly contributed to minimizing X-ray radiation damage.

Comparing the pre-puncture positioning time between the two groups, the real-time ultrasound-guided combined with CT monitoring group exhibited a shorter duration than the sole CT-guided group. This can be attributed to the direct and accurate localization of the target intervertebral disc plane under ultrasound guidance, which is rapid, precise, and radiation-free. In contrast, the sole CT-guided group relied mainly on tactile surface markings for pre-puncture positioning and required additional CT confirmation, thereby increasing the pre-puncture positioning time to some extent.

When comparing the total puncture time between the two groups, the real-time ultrasound-guided combined with CT monitoring group showed a shorter duration than the sole CT-guided group. Reducing the total puncture time is advantageous for enhancing patient comfort and reducing anxiety. In this study, the operators in the real-time ultrasound-guided combined with CT monitoring group had over five years of musculoskeletal ultrasound intervention experience, demonstrating a relatively proficient mastery of this technique, resulting in minimal differences in total puncture time. In contrast, the sole CT-guided group exhibited a larger variation in total puncture time, with the shortest guidance time being only 9 minutes and the longest reaching 21 minutes. This variation may be associated with objective factors such as patient physique and degree of osteophyte formation. Additionally, the stepwise needle advancement technique employed by orthopedic surgeons in the spine department, requiring multiple CT surveillance-assisted adjustments, contributed to the increased total puncture time.

In this study, two cases of hematoma occurred in the sole CT-guided group, while no apparent complications were observed in the real-time ultrasound-guided combined with CT monitoring group. This underscores the clear visualization of the needle's relationship with neck vessels, especially the vertebral artery, nerves, and intervertebral disc, under real-time ultrasound guidance. Throughout the puncture process, avoidance of vascular and neural structures was facilitated, ensuring precise insertion of the puncture needle into the right anterior margin of the target intervertebral disc. After CT verification, the needle was advanced under ultrasound guidance to the central portion of the intervertebral disc, and following another CT confirmation, the needle core was withdrawn. Subsequent drug injection was administered under ultrasound visualization, allowing observation of drug dispersion within the intervertebral disc. This comprehensive approach minimizes the risk of a small amount of bupivacaine leaking from the cervical intervertebral disc and exerting an anesthetic effect on cervical nerve roots. Furthermore, real-time ultrasound allows observation of the spread of blocking agent fluid, as various factors such as drug volume and injection speed can influence fluid dispersion.[28]

Limitations

The study population included patients with cervical discogenic dizziness, and the findings may not be directly applicable to individuals with other cervical spine conditions. The heterogeneity of patient presentations and underlying cervical spine pathology could impact the generalizability of the results. Besides, the study primarily focused on the procedural aspects and immediate outcomes. Long-term follow-up data, particularly regarding the persistence of therapeutic effects and the occurrence of delayed complications, were not systematically collected. Future studies with extended follow-up periods are warranted to assess the durability of the intervention. Furthermore, the proficiency of the operators in the real-time ultrasound-guided combined with CT monitoring group, each with over five years of musculoskeletal ultrasound intervention experience, may have influenced the outcomes. The results might not be easily replicable in settings where operators are less experienced in this specific technique.

Conclusion

This study demonstrates the advantages of real-time ultrasound guidance combined with computed tomography monitoring in percutaneous cervical intervertebral disc injection for both diagnostic and therapeutic purposes. The reduction in computed tomography exposures, shorter pre-puncture positioning time, and decreased total puncture time contribute to improved procedural efficiency and patient outcomes. The absence of complications in the real-time ultrasound-guided group further emphasizes the safety and precision of this combined approach, particularly in avoiding potential damage to critical structures in the cervical spine.

Funding

There is no funding to report.

Disclosure

The authors report no conflicts of interest in this work.

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