Original Article

Accuracy of Plain Radiography in Cervical Spine Injury

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Abstract

Background and Objectives: Routine clinical examination and plain radiography are reportedly inadequate for the determination of cervical injury. Accordingly, it is required to perform computed tomography (CT) scan on the cervical spine in suspected trauma cases, even in those with normal clinical examination findings. However, the risk of radiation and financial charges should be also considered in these cases. Therefore, the present study was conducted to compare the accuracy of plain radiography with that of CT (a gold standard) in the evaluation of cervical spine injury. **Materials and Methods:** This diagnostic study was conducted on 220 trauma patients (the mean age of 38.25 ± 5.13 years) referred to the Emergency Department of Besat Hospital, Hamadan, Iran, from April 2019 to March 2020. The patients with the National Emergency X-Radiography Utilization Study low-risk criteria underwent CT and plain radiography. **Results:** According to the results, 210 (95.5%) patients were normal in both imaging modalities. Out of 10 patients with abnormal CT, four patients were detected by the plain radiography. Therefore, the plain radiography had the sensitivity, specificity, negative predictive value, and positive predictive value of 40%, 100%, 97.2%, and 100%, respectively. **Conclusions**: As the findings indicated, plain radiography was inadequate for the definite exclusion of cervical spine injury. Therefore, this modality should be considered only in low-risk patients. On the other hand, patients with moderate and high probability of injuries need to undergo a CT scan as the only and first screening imaging modality. However, a low-dose CT scan is a preferred protocol for this group of patients.

Keywords: Blunt trauma, cervical spine computed tomography, cervical spine injury, cervical spine radiographs

Introduction

The risk of cervical spine injury in blunt trauma is reported to vary from 1% to 11.5%.[1-3] Based on the evidence, routine clinical examination and conventional three-view plain cervical radiographs are inadequate for the exclusion of cervical injury.[4,5] Accordingly, it has been suggested to perform a computed tomography (CT) scan of the cervical spine in cases with suspected trauma, even if having normal clinical examination results.[5] However, a CT scan is accompanied by the risk of radiation and financial charge.[6,7] Missing cases of injuries involve physicians, patients, and the entire health-care system. Meanwhile, early and correct diagnosis of cervical injury prevents the incidence of potential irreversible neurological deficits. There are a couple of evidence-based guidelines, namely, the National Emergency Utilization Study (NEXUS) and Canadian C-spine Rule (CCR) to determine the blunt trauma patients who need to be subjected to diagnostic imaging. These guidelines, along with the available imaging protocols, facilitate the prevention of performing unnecessary medical imaging procedures.[8,9] Conventionally, plain radiography has been accepted as the primary standard screening test. However, this procedure fails to facilitate the correct diagnosis of the entire cervical spinal injury. Additional flexion-extension and oblique supine radiography[10,11] are the new approaches proposed recently.

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Griffen *et al*. reported a sensitivity of only 65% for plain radiography versus 100% for cervical CT.[12] The low sensitivity of plain films has been also indicated in several other studies. According to some published research, plain cervical X-ray has a missed injury rate of 23%–61%.[3,13,14] However, the overuse of CT scan in recent years has resulted in the elevation of unnecessary radiation exposure in patients with blunt trauma. As stated by Sheikh *et al*., 96.9% of patients undertake cervical CT,[9] while most of them have negative CT findings.

Regarding this, the optimal imaging modality for cervical spinal injury remains controversial. The determination of such a modality requires the consideration of some important factors including availability, sensitivity, specificity, radiation dose, and cost-effectiveness. The appropriate screening test for ruling out spinal injury is still unclear. Therefore, the present study was conducted to assess the accuracy of plain radiography in the identification of cervical spinal injuries after blunt trauma.

Materials and Methods

This prospective study was conducted on trauma patients referred to emergency department of Besat Hospital, Hamadan, Iran, from, April 2019 to March 2020. Study approval was obtained from the Institutional Review Board of Hamadan University of Medical Sciences, Hamadan, Iran. The inclusion criterion was a low-risk status based on the international NEXUS criteria. On the other hand, those with penetrating trauma were excluded from the research. The collected data included demographic information (e.g., age and gender), mechanism of injury, level of consciousness, and injury severity score.

The patients were subjected to both CT scan and plain radiography. Plain radiographs were obtained in three views (i.e., anteroposterior, lateral, and odontoid). In addition, cervical CT was performed using a 16-slice multidetector CT scanner (Somatom GE health care) in a supine position. Images started with lateral scout images from the foramen magnum to the junction of the C7-T1 vertebral Junction. The standard scan protocols included the voltage of 130 kV, collimation of 1 mm, pitch of 0.66, and tube current-time product of 200 mAs. Coronal and sagittal reformation images were reconstructed using 1.5-mm intervals from an axial source on a standard workstation.

Interpretation of plain radiographs and cervical CT images was performed by two experienced, board-certified radiologists blinded to the results. Cervical spine injury was defined as subluxation/dislocation or acute fracture or both. Final blinded readings of plain radiography and cervical CT were recorded for each patient. A clinically significant injury was determined based on the neurosurgical recommendation of one or more interventions, namely, operation and rigid cervical collar or halo application. Specificity, sensitivity, negative predictive value, and positive predictive value were calculated for plain radiography and CT scan of clinically significant injuries.

Results

A total of 220 patients (157 males), with the mean age of 38.25 ± 5.13 years, participated in this study (35% between 26 and 35 years). The most common mechanisms of injuries were car accidents (64%) and falls from height (17.7%) [Figure 1]. Based on the CT scan, 10 patients (4.5%) were detected with such injuries as fracture and/or dislocation, and the rest had normal findings. However, only four patients (40%) were detected by plain radiography and review of the false-negative results (six patients) demonstrated that three patients were clinically significant [Table 1]. Figures 2 and 3 show the CT and radiographic results of two patients as examples. With regard to plain radiography, it had the sensitivity, specificity, LR+, LR−, negative predictive value, and positive predictive value of 40%, 100%, ∞, 60%, 97.2%, and 100%, respectively.

Discussion

The CCR and NEXUS criteria are two clinical tools facilitating the determination of the need for diagnostic imaging in blunt trauma patients. The NEXUS criteria are highly sensitive (99%) but nonspecific (12.7%).[15] However, the CCR has shown high sensitivity, as well as reasonable specificity (43%).[16] Nonetheless, some clinicians do not apply the CCR or NEXUS criteria and use their own discretion to decide on the sufficiency of plain radiography or the need for a cervical CT scan. The present study aimed at evaluating the accuracy of plain radiography in detection of the cervical spine and clinically significant injuries after blunt trauma. Our results are consistent with those of previous research. Generally, 10%–20% of clinically significant injuries are missed by plain films. Plain radiography includes anteroposterior, open-mouth odontoid, and lateral views.

According to multiple studies, plain radiographic evaluation is not adequate for the determination of cervical spine injury,[17-20] given its low sensitivity to detect clinically significant injuries. In a study conducted by Diaz *et al*., the sensitivity and specificity of five-view plain films were, respectively, obtained as 44% and 100%, while those of CT scan were presented as 97.4% and 100%, respectively.[21] Furthermore, in another

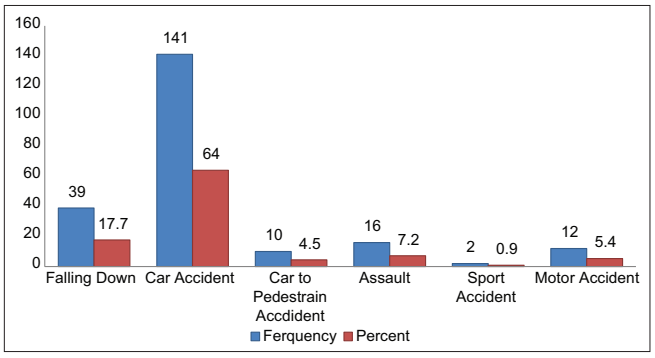

Figure 1: The percentage and frequency of the mechanism of injury in patients referred with cervical blunt trauma to the emergency department of Besat Hospital in Hamadan from April 2019 to March 2020

study, Widder *et al*. reported a sensitivity of 39% for plain films.[18] In the present study, 60% of the injuries ($n = 6$) were missed by plain radiography. In addition, there were three cases of clinically significant injuries missed on plain films. This missing rate is unacceptable, given the long-term and chronic neurological deficits and disabilities that may arise after diagnostic failure.

The results of the present study were indicative of the inadequacy of plain radiography for evaluating and ruling out cervical spine injuries in moderate-to-high-risk patients. It was also established that plain radiography is often technically inadequate to fully evaluate the cervical spine and that, in most cases, further evaluation with CT is needed.

In a meta-analysis, the sensitivity rates of plain films and cervical CT were reported as 52% and 96%, respectively.[22] In addition, Mathen *et al*. reported a sensitivity of 100% for CT in all acute injuries in comparison with 45% for plain films.

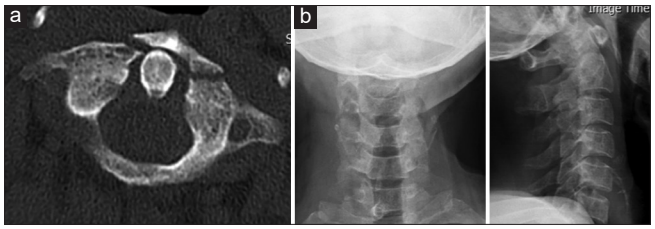

Figure 2: (a) Axial computed tomography scan from cervical spine at C1–C2 level. (b) AP and lateral plain radiograph; fracture of anterior arch of C1 detected by axial computed tomography, and missing in plain radiograph

Accordingly, they suggested the plain films to be insufficient for the determination of spinal injuries with missing 55.6% of fractures.[23] The quality of plain radiographs is also an important issue. Mower *et al*. also reported a sensitivity of 60.1% for plain radiography. However, they obtained a sensitivity of 89.4% after the exclusion of the plain films inadequate to detect at least one injury.[24]

In a study carried out by Bailitz *et al*., the plain films with adequate radiographs in comparison with inadequate films had the sensitivity rates of 63% and 36%, respectively. They also classified patients as low, moderate, and high-risk patients according to the mechanism of injury and the NEXUS criteria. They observed that plain film sensitivity was different in low-, moderate-, and high-risk patients (25%, 37%, and 46%, respectively).[25] In a prospective study carried out by Mathen *et al*. on 667 trauma patients, the sensitivity and specificity of cervical CT were significantly better than those of plain films (100% and 99.5% versus 45% and 97.4%, respectively).[23] Griffen *et al*. reported 100% sensitivity for CT scan since it facilitated the detection of all 116 injuries; however, plain films identified injuries with a lower sensitivity (65%).[12]

In a systematic review performed by Benton,[26] the performance of the plain film was reported to be poor. On the other hand, Benton *et al*. claimed that the mentioned review study entailed some methodological pitfalls including the nonblinding of the radiologist, lack of gold standard, and prospective design. Saltzher *et al*. reported 34.7% of patients with plain film needed to undergo a CT scan for further evaluation. The main reasons for the requirement of a subsequent cervical CT

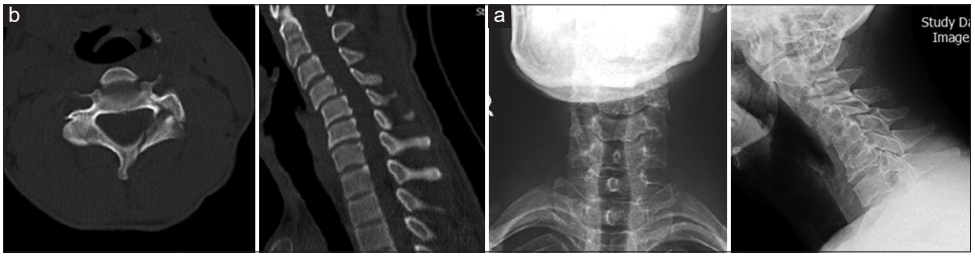

Figure 3: (a) Lateral and AP plain radiograph. (b) Sagittal reconstruction and axial computed tomography; computed tomography images shows fracture in the laminae and pedicle of C4 vertebra, plain radiograph only shows mild antrolisthesis at C4-C5 level and reverse kyphosis in lateral view

Table 1: The frequency of lesion levels in computed tomography of 10 patients and their plain radiographic results

Patient	Lesion		Plain radiography	Clinically significant
	Fracture	Dislocation		
1	Anterior arch (C1)	C1	Missed	Yes
2	Posterior arch (C1)	-	Missed	Yes
3	Transverse process (C5 and C6)	-	Missed	No
4	Transverse process (C4)	-	Missed	No
5	Body (C3)	C2	Missed	Yes
6	Spinous process (C6 and C7)	-	Detected	No
7	Body compression (C2)	C4	Detected	No
8	Mild body compression (C5 and C7)		Detected	No
9	Pedicle and lamina (C4)	C4	Missed	No
10	Mild body compression (C4)	-	Detected	No

scan after undergoing plain radiography are the inadequate visualization of cervicothoracic junction (72%) and C1 and C2 vertebra (14%).[27]

In two studies carried out by Hashem *et al*.[27] and Sheikh *et al*.,[28] 19.1% and 7.1% of patients had clinically significant fractures, which were visualized on CT but missed on plain radiography. In the present study, 3 (30%) out of 10 patients with cervical spine injuries had clinically significant injuries, which were detected by CT but missed on plain radiography. Regarding these findings, this question arises whether a CT scan should replace plain radiography as the primary imaging test. There is no doubt that CT scan is superior in detecting injuries. However, in a study, Sheikh reported that 96.8% of the patients received an unnecessary cervical CT scan.

In the present study, 210 patients (95.5%) were normal in both imaging modalities and therefore received an unnecessary CT scan. This is compatible with other similar reports. Anatomic details in CT scans have significantly higher visibility. Accordingly, some patients who need further evaluation are subjected to a cervical CT scan. This not only adds to the workload of radiologists, technicians, and trauma team but also increases patient radiation exposure and costs. Exposure to radiation is a significant issue in cervical CT due to the radiosensitivity of the thyroid gland. Risk–benefit ratio between radiation-induced malignancy and missed fracture will be investigated. The radiation dose in cervical CT is significantly higher than the dose applied in plain radiography. For instance, the mean thyroid exposure dose in cervical CT is 14 folds higher than that of plain radiography (26 mGy versus 1.8 mGy) with 95% confidence limits. This elevated dose may heighten the long-term risk of malignancy. In the same vein, the increased use of cervical CT for the determination of cervical spine injury can be accompanied by serious consequences.

The two modalities also differ in terms of the implementation time. A plain film is taken in a few minutes, whereas a CT scan requires a longer time. Moreover, a CT scan is accompanied by a higher level of patient discomfort, as well as higher costs. Tan *et al*., addressing a cost-effective approach, investigated the patients who needed further evaluations with the segmental CT scan of C7-T1 after undergoing primary plain radiography. They reported that, since the charges of complete and partial CT scans are the same, the patients who underwent plain film evaluation, followed by segmental CT scan, were charged more than those subjected to complete CT scan at the first stage.[29]

In a cost analysis study carried out by Grogan *et al*., the institutional cost for cervical CT was reported as $554, compared with $2.142 for plain radiography. They emphasized that 0.9% probability of cervical fracture and 1.7% probability of paralysis is not cost effective. Accordingly, they concluded the CT scan as a preferred modality only in moderate-to-high-risk patients.[30] There is no doubt regarding the superiority of CT scan to plain radiography. However, cost and radiation are also important issues that should be considered. Plain radiography delivers a dose of 0.2 mSv, while a cervical CT scan exposes the patient to a dose of about 4–6 mSv. This is especially important in young adults owing to the long-term carcinogenic effect of radiation.

In an attempt to perform a cost-effectiveness analysis, Blackmore *et al*. stratified trauma patients into three levels of probability based on clinical findings on admission. They recommended the CT scan as the first imaging modality that should be performed on high-risk patients (i.e., cases with more than 10% probability of injury) and those with a moderate probability of fracture (4%–10%). On the other hand, they acknowledged the use of plain radiography for low-risk patients since the implementation of CT scan for this group of patients is not cost effective.[29]

The application of the NEXUS criteria, along with plain radiography, in low-risk group's results in the reduction of a considerable number of negative cervical CT scans. Therefore, it is required to optimize and adjust the indication of CT scan in patients with a low risk of cervical spine injury. There are a number of new studies investigating the use of low-dose CT scan for the evaluation of cervical spine injury and comparing the standard-dose and low-dose CT scans. In this regard, Mulkenes *et al*.[31] concluded that a low-dose CT scan (i.e., a voltage of 110 kV and mAs of 125) in comparison with a standard-dose CT (i.e., a voltage of 130 kV and mAs of 200–250) resulted in the reduction of the CT dose index from 24 mGy to 15 mGY. Therefore, low-dose protocols led to a reduction of 61%–71% in the mean dose. Furthermore, a lower tube voltage and tube current modulation were reported to provide a proper setting for the adequate imaging of cervical spine injuries.

The low-dose protocol is reportedly accompanied by a subtle increase in the image nose. However, Mulkenes *et al*.[31] observed no statistically significant difference between the two protocols in terms of image quality using the Kruskal–Wallis test. In addition, the results revealed no significant difference between the two mentioned protocols regarding diagnostic accuracy. In another study, Mclaughlin *et al*. addressing the low-dose cervical CT scan showed that this protocol induced a significant drop in an effective radiation dose in comparison with the standard dose protocols (0.6 mSv vs. 6 mSv).[32] In addition, Kim *et al*., emphasizing the low-dose CT for the initial evaluation of blunt trauma,[33] demonstrated that low-dose protocols were accompanied by minimized radiation dose using lead shielding on the breast and gonads. They also suggested to consider the adjustment of body habitus during exposure to reduce the exposure dose. It is dependent on the amount of care taken by technicians and radiologists when determining the appropriate protocols, the radiation will become less over time. The establishment of definite and accurate clinical decisions in patients with a high-risk traumatic injury is an issue of significant importance. Therefore, the clinicians should be able to accurately decide on the need for undergoing a CT scan in these patients.

Our results were indicative of the superiority of the cervical CT scan as a screening modality in the evaluation of

moderate- and high-risk patients. However, it is recommended to use a low-dose CT scan for this group of patients. It is known that some injuries are missed in plain radiography; however, the clinical significance of missing injuries is not clear yet. Therefore, the clinically significant injuries should be considered in this regard.

Plain radiography is an adequate procedure to be adopted for low-risk patients. However, short segment low-dose CT is also recommended for the low-risk patients whose radiographs are inadequate for diagnosis or indicate a suspected condition. Despite the importance of the issue, there are insufficient studies evaluating the accuracy of plain films in low-risk patients. Therefore, it is required to perform large-scope prospective trials to determine the utility of plain radiography in cervical blunt trauma. In pediatrics groups, the injuries are seen in a higher cervical spine level (C1 through C3). Aarons *et al*. recommended magnetic resonance imaging for the evaluation of pediatrics groups.

The present study entailed some limitations including a small sample size, inadequate plain films, which were not repeated. In addition, the present study did not involve the evaluation of possible ligament, disc, and spinal cord injuries. As another limitation, the patients were not followed up until discharge to evaluate the late neurologic complications. Future complementary studies are recommended to investigate the efficiency of low-dose CT for the evaluation of the cervical spine and to compare standard-dose and low-dose CT scans.

Conclusion

As the findings indicated, three-view plain radiography is an adequate modality for the evaluation of low-risk patients. However, moderate and high-risk patients should be only subjected to cervical CT scan as the primary imaging modality without plain radiography. Therefore, effort should be made to balance among the probability of fracture, missing injury, and risk of radiation-induced malignancy.

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Conflicts of interest

There are no conflicts of interest.

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