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Multi-detector computed tomography evaluation of suspected acute blunt cervical spine trauma in adult patients at King Chulalongkorn Memorial Hospital

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Background : *According to the American College of Radiology (ACR) appropriateness criteria for imaging of suspected spine trauma, multi-detector computed tomography (MDCT) is the recommended screening imaging procedure in adult patients with high-risk criteria by national emergency x-radiography utilization study (NEXUS) criteria and the Canadian cervical spines rule (CCR).*

Objectives : *To evaluate imaging features of cervical spine fracture and to assess the anappropriateness of performing cervical spine CT according to NEXUS criteria and CCR at the emergency room of King Chulalongkorn Memorial Hospital (KCMH).*

Design : *Retrospective study.*

Setting : *King Chulalongkorn Memorial Hospital.*

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Material and Methods : *Our study recruited cervical spine CT images performed at the ER from November 2012 to October 2013 in adult patients suspected of acute cervical spine injury. Patients aged <18 years, non-acute trauma settings (≥ 72 hours), non-traumatic conditions, penetrating cervical injuries and refer red cases from other hospitals were excluded from this study.*

Results : *Of the 150 cervical spine CT studies analyzed, 15 (10%) were positive for cervical fracture as followings; Clay shoveler fracture, burst fracture, transverse process fracture, Hangman's fracture, dens/odontoid process fracture, hyperextension fracture dislocation and inferior endplate fracture. 137 (91.3%) patients with documented clinical indication for ordering cervical spine CT underwent cervical spine CT properly based on NEXUS criteria or CCR. The remaining 13 (8.7%) patients had no documentation about clinical indication but subsequent imaging showed no cervical spine fracture. Additionally, 51% (76/150) of the patients performed both cervical spine CT and cervical spine radiographs, in which being considered as "inappropriate".*

Conclusions : *Strict application of the ACR appropriateness criteria into practical use could reduce some CT over utilization and dramatically decrease the rate of unnecessary radiographs to clear the cervical spine.*

Keywords : *Cervical spine CT, blunt cervical spine trauma, NEXUS, CCR.*

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จุฑาภรณ์ สุระเวช, ศศิธร เพชรจรัลไพศาล. การประเมินผู้ป่วยที่สงสัยภาวะบาดเจ็บที่กระดูกสันหลังส่วนคอโดยใช้เอกซเรย์คอมพิวเตอร์ในโรงพยาบาลจุฬาลงกรณ์. จุฬาลงกรณ์เวชสาร 2559 มี.ค. – เม.ย.; 60(2): 143 – 53

เหตุผลของการทำวิจัย : *ตามหลัก ACR appropriateness criteria เอกซเรย์คอมพิวเตอร์ถือเป็นภาพรังสีเบื้องต้นที่ใช้ในการประเมินผู้ป่วยที่สงสัยภาวะบาดเจ็บที่กระดูกสันหลังส่วนคอ และมีความเสี่ยงสูงตามเกณฑ์ NEXUS หรือ CCR*

วัตถุประสงค์ : *เพื่อศึกษาลักษณะภาพรังสีของกระดูกสันหลังส่วนคอหัก/แตกและเพื่อประเมินความเหมาะสมในการทำเอกซเรย์คอมพิวเตอร์บริเวณกระดูกสันหลังส่วนคอตามหลักเกณฑ์ NEXUS หรือ CCR ในผู้ป่วยที่สงสัยภาวะบาดเจ็บที่กระดูกสันหลังส่วนคอที่ห้องฉุกเฉินของโรงพยาบาลจุฬาลงกรณ์*

รูปแบบการวิจัย : *การศึกษาย้อนหลังเชิงพรรณนา*

สถานที่ทำการศึกษา : *โรงพยาบาลจุฬาลงกรณ์*

ตัวอย่างและวิธีการศึกษา : *ผู้ป่วยที่สงสัยภาวะบาดเจ็บที่กระดูกสันหลังส่วนคอได้รับการทำเอกซเรย์คอมพิวเตอร์ที่ห้องฉุกเฉินของโรงพยาบาลจุฬาลงกรณ์ ตั้งแต่เดือนพฤศจิกายน พ.ศ. 2555 ถึง เดือนตุลาคม พ.ศ. 2556 จำนวนทั้งหมด 190 ราย ผู้ป่วยที่ถูกคัดออกจากการศึกษานี้ ได้แก่ ผู้ป่วยที่อายุต่ำกว่า 18 ปีผู้ป่วยที่ได้รับบาดเจ็บจากของมีคมหรือเกินสามวันขึ้นไป หรือเป็นผู้ป่วยที่ถูกส่งตัวมาจากโรงพยาบาลอื่น*

ผลการศึกษา : *1) จากผู้ป่วยทั้งหมด 150 ราย มี 15 รายที่มีกระดูกสันหลังส่วนคอหัก/แตก 2) ผู้ป่วยจำนวน 137 ราย (91.3%) ที่มีบันทึกข้อบ่งชี้ในการทำเอกซเรย์คอมพิวเตอร์บริเวณกระดูกสันหลังส่วนคอในเวชระเบียนได้รับการทำเอกซเรย์คอมพิวเตอร์เหมาะสมตามหลักเกณฑ์ NEXUS หรือ CCR 3) ผู้ป่วยที่เหลือ 13 ราย (8.7%) ไม่มีการบันทึกข้อบ่งชี้ในการทำเอกซเรย์คอมพิวเตอร์ และไม่พบว่ามีการหัก/แตกของกระดูกสันหลังส่วนคอจากเอกซเรย์คอมพิวเตอร์ 4) 51% ของผู้ป่วยได้รับการตรวจทั้งเอกซเรย์คอมพิวเตอร์และการถ่ายภาพรังสีเอกซ์ (plain radiography) ซึ่งไม่เป็นไปตามหลักเกณฑ์ NEXUS หรือ CCR*

สรุป : *การศึกษานี้พบว่าถ้าแพทย์ที่ห้องฉุกเฉินใช้ ACR appropriateness criteriaประเมินผู้ป่วยที่สงสัยภาวะบาดเจ็บที่กระดูกสันหลังส่วนคออย่างเข้มงวด จะช่วยลดการทำเอกซเรย์คอมพิวเตอร์ในผู้ป่วยบางรายได้ และสามารถลดการถ่ายภาพรังสีเอกซ์ที่ไม่จำเป็นได้อย่างมาก*

คำสำคัญ : *เอกซเรย์คอมพิวเตอร์บริเวณกระดูกสันหลังส่วนคอ, การบาดเจ็บที่กระดูกสันหลังส่วนคอ, หลักเกณฑ์ NEXUS, หลักเกณฑ์ CCR.*

Cervical spine clearance after blunt trauma is defined as accurate confirmation of the absence of a cervical spine injury. In the United States, more than one million blunt trauma patients with questionable acute cervical spine injury visited the ER each year[1]; however, the incidence of definite cervical spine injury is approximated 2 - 10% of such cases.[2] Regarding high morbidity and high mortality resulted from unrecognition and delayed diagnosis of cervical spine injury, there is a high tendency to perform cervical spine imaging to rule out the cervical spine injury in patients with blunt trauma.

In order to optimize radiation exposure and cost-effectiveness of cervical spine imaging, careful selection of patients who are truly at risk and need imaging is required. There are two widely accepted evidence-base decision rules derived from prospective observational cohort multicenter trials: the NEXUS criteria and the CCR criteria. These two decision criteria have been included in the ACR appropriateness guidelines as a means of screening patients before imaging the cervical spine.

The NEXUS criteria were established to identify patients with a low probability of cervical spine injury, in whom imaging of cervical spine was unnecessary.[3 - 5] The NEXUS criteria includes the followings: absence of midline cervical tenderness, no focal neurological deficit, normal alertness, no evidence of intoxication and no painful distracting injury (Table 1).

Table 1. The NEXUS criteria: cervical spine injury cannot be excluded if any criterions are present.[4]

1. Posterior midline cervical tenderness
   - Present if pain is elicited on palpation of the posterior cervical midline from the nuchal ridge to the prominence of the first thoracic vertebra, or if pain is reported on palpation of any cervical spinous process.
2. Altered mental status
   - Glasgow coma scale (GCS) $\leq$ 14
   - Disorientation to time, place, person or events
   - Inability to remember three objects at 5 minutes
   - Delayed or inappropriate response to external stimuli
3. Focal neurologic deficit
   - Any patient-reported or examiner-elicited neurologic deficit
4. Evidence of intoxication
   - Recent history reported by the patient or an observer of intoxication or intoxicating ingestion
   - Evidence of intoxication on physical examination, such as odor of alcohol, slurred speech, ataxia, dysmetria, or other cerebellar findings
   - Behavior consistent with intoxication
   - Tests of bodily secretions are positive for drugs (including but not limited to alcohol) affecting mental alertness
5. Painful distracting injury
   - Any condition thought by the clinician to be producing pain sufficient to distract the patient from a cervical spine injury. Examples may include:
   - any long bone fracture
   - a significant visceral injury
   - a large laceration, degloving injury, or crush injury
   - extensive burns
   - any other injuries producing acute functional impairment

The CCR criteria uses three high-risk criteria, three low-risk criteria, and the ability of patients to actively rotate their necks to determine the need for cervical spine radiography[6] (Figure1).

Michaleff *et al*. conducted a systematic review to investigate the diagnostic accuracy of the CCR criteria and NEXUS criteria. They found that the CCR criteria had higher sensitivity, higher specificity and higher accuracy as compared to the NEXUS criteria. However, the NEXUS criteria are applied to all age groups, whereas the CCR criteria are only applied to patients aged 16 - 65 years; both sets of criteria have been shown to be powerful predictors of cervical spine injury.[7]

According to the current version of ACR appropriateness criteria for imaging of suspected spine trauma, MDCT with sagittal and coronal reconstruction is the recommended screening imaging procedure in adult patients with high-risk criteria by NEXUS or CCR. Radiography is the imaging procedure of choice in children age 14 years and under. Radiography has limited use in the adult and should be used primarily applied for resolving nondiagnostic CT studies due to motion artifacts.[8]

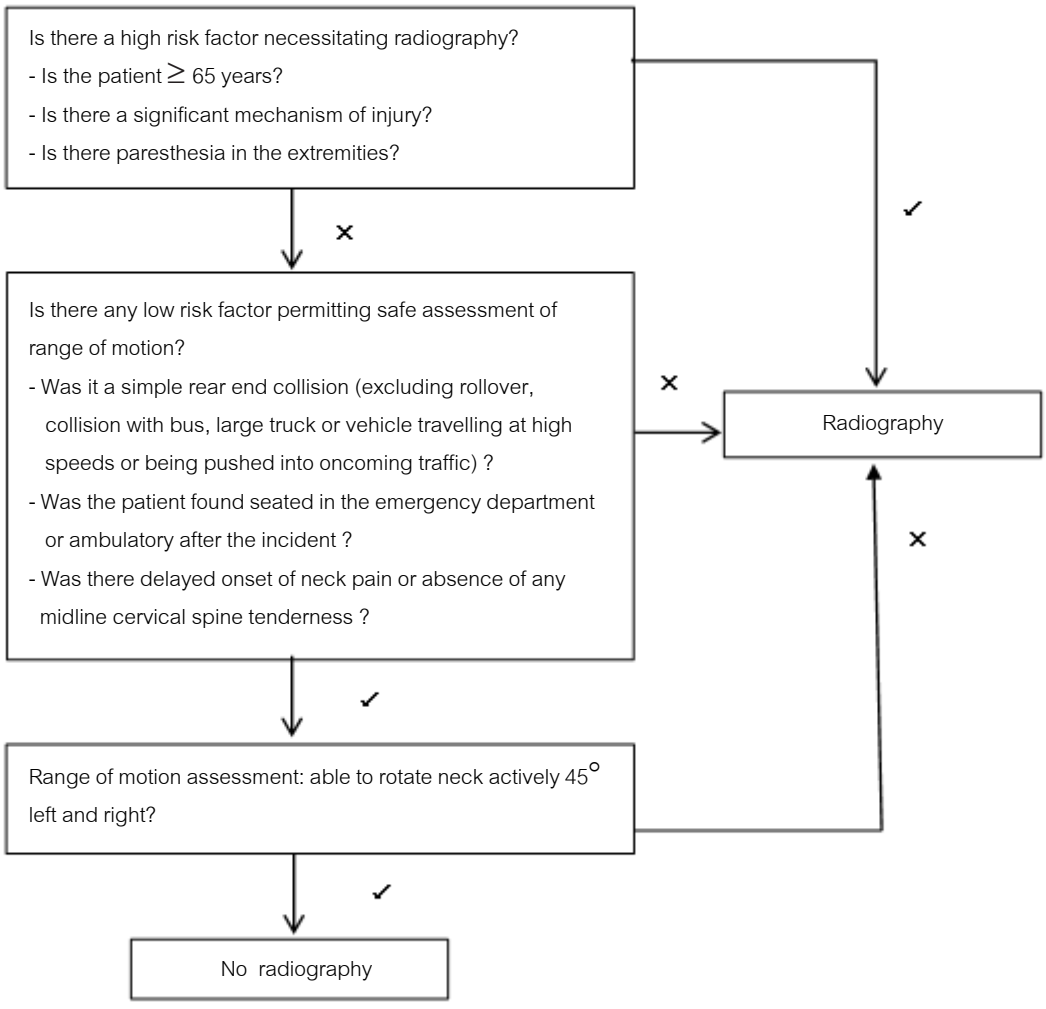

Figure 1. The CCR criteria.

At KCMH, when acute blunt trauma patients with possibility of cervical spine fracture visit the ER, the primary emergency physicians will order cervical spine CT following the 8th or the 9th editions of advanced trauma life support (ATLS) guideline, NEXUS criteria, CCR or others.

Even though NEXUS criteria and CCR have been proposed, the study of their integration to real clinical situations are still limited. The aims of this study are to review imaging features of cervical spine fracture and to assess the appropriateness of performing cervical spine CT according to these two international appropriateness criteria.

Methods:

Population

The patients presenting to ER at KCMH from November 1st 2012 to October 31st 2013 who underwent MDCT of cervical spine at CT scanner installed in the ER (Philips, Brilliance 64; axial scan, 40 × 0.625 collimation, 1.0 mm slice thickness) were eligible for the study.

Review of demographic data (sex and age), clinical presentations, indication for ordering the study and complications after negative studies was performed.

Inclusion criteria were adult patients with suspected acute cervical spine injury performing cervical spine CT with/without cervical spine radiographs within 72 hours after blunt trauma. Exclusion criteria were patients with age < 18 years, non-acute trauma settings (≥72 hours), non-traumatic conditions, penetrating cervical injuries and referred cases from other hospitals.

Image analysis

Two reviewers (a second year radiology resident and a 6-year-experienced neuroradiologist) retrospectively assessed the cervical spine CT images independently. Any disagreement was resolved upon discussion. Evaluation of cervical spine CT appropriateness based on NEXUS criteria or CCR was determined by the second year radiology resident. Total numbers of cervical spine CT performed alone, and both cervical spine CT and radiographs performed on the same patient, were additionally analyzed. According to ACR appropriateness criteria, MDCT scan was the initial assessment in patients suspected acute cervical spine trauma. Thus, in patients investigated by both CT and radiograph were considered as “inappropriate”.

Statistical analysis

The percentage of cervical spine fracture was calculated and inter-rater reliability was measured with Kappa method of analysis.

Results

A total of 190 cervical spine CT images were performed in adult patients suspected of acute cervical spine injury at the ER of KCMH from November 2012 to October 2013. Forty studies were recruited (patients with age < 18 years; N =10, non-acute trauma settings (≥72 hours); N = 2, non-traumatic conditions; N = 5, penetrating cervical injuries; N = 4, referred cases from other hospitals; N = 18 and no clinical recorded; N = 1). Therefore, cervical spine CT images recruited in this study were 150 studies.

One hundred and six patients were male and 44 patients were female (Figure 2). Patient ages ranged from 18 to 90 years with the mean age of 43.7years. There were 125 patients who aged 18 - 65 years and 25 patients who aged more than 65 years (Figure 3).

From our study, car accidents were the most common cause of blunt injury, accounting for 46.7%, followed by falls (29.3%), unknown causes (14%) and others (including body assault, direct object falling on the head and electric shock) (10%). In the elderly subgroup (aged above 65 years), falls were the most common cause (60%), followed by car accidents (28%) (Figure 4).

Of the 150 patients, 137 (91.3%) had medical records of clinical indication for ordering cervical spine CT ; all of these patients underwent cervical spine CT properly based on NEXUS or CCR criteria.

The most common clinical indication for performing cervical spine CT was alteration of consciousness (48%). Midline cervical tenderness was the second most common, followed by evidence of drug or alcohol intoxication, inability to actively rotate neck, focal neurologic deficit and presence of other injuries considered painful enough to distract from neck pain (26.7%, 6%, 4%, 3.3% and 3.3% respectively) (Table 2).

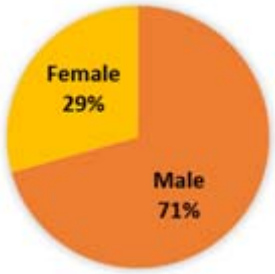

Figure 2. Sex

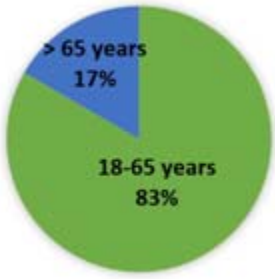

Figure 3. Age

Figure 4. Cause of blunt injury.

Table 2. Indication for ordering cervical spine CT.

Indication for CT	No. (%)
Altered mental status	72 (48)
Midline cervical tenderness	40 (26.7)
Evidence of drug or alcohol intoxication	9 (6)
Unable to actively rotate neck	6 (4)
Focal neurologic deficit	5 (3.3)
Presence of other injury considered painful enough to distract from neck pain	5 (3.3)
Unknown	13 (8.7)

The remaining 13 (8.7%) patients had no documentation about clinical indication for performing the study. However, none had cervical spine fracture. Furthermore, 51% (76/150) received both cervical spine CT and radiographs, considered as "inappropriate"; and 49% (74/150) only had cervical spine CT.

Our findings yielded a result of 10% (15/150) of all patients with cervical spine CT demonstrating cervical spine fracture as followings (Table 3):

- Clay shoveler fracture 3 cases
- Burst fracture of cervical spine 3 cases
- Fracture of transverse process 3 cases
- Hangman's fracture 2 cases
- Fracture of dens/odontoid process 2 cases
- Hyperextension fracture dislocation 1 case
- Inferior endplate fracture 1 case

According to the lack of data of blunt trauma in patients who did not receive cervical spine CT, which was a limitation, we could not evaluate the actual incidence of cervical spine fracture at KCMH. Nevertheless, it is estimated that the incidence of cervical spine fracture in blunt trauma patients who underwent screening CT was about 10%.

From 135 patients with negative CT imaging, 95% (128/135) revealed no documented evidence of readmission or neurologic deficit after discharge, 4.4% (6/135) were dead from other complications and one patient was referred to another hospital.

The inter-rater reliability of cervical spine CT interpretation showed substantial agreement (Kappa = 0.86, p <0.001).

Discussion

Cervical spine trauma is a disastrous event, causing high morbidity and mortality (e.g. spinal cord injury and death if delayed or missed diagnosis) including medical, psychological, social, and financial consequences.

In KCMH, the incidence of cervical spine fracture in blunt trauma patients who underwent screening CT was 10%.

Correspondence with the previous publication by Munera *et al*, our study showed that cervical spine fractures are more likely to be caused by low mechanisms (e.g. fall from standing height) in patients more than 65 years.[9]

Table 3. Data of patients with positive CT findings.

No.	Imagings	Sex	Age	Cause	Indication for CT	CT findings (Reader1)	CT findings (Reader 2)	Consensus
1	Both	F	25	MCA	Alteration of consciousness	Hangman's fracture		-
2	Both	M	20	MCA	Alteration of consciousness	Fracture of C7 spinous process		-
3	CT alone	M	35	Fall	Alteration of consciousness	Comminuted fracture of C5 + Burst fracture of C6		-
4	Both	M	64	Fall from height	Monoparesis right arm	Extension distraction injury of C5/6		-
5	CT alone	M	32	Fall from vehicle	Alteration of consciousness	Fracture of left C7 transverse process		-
6	Both	M	32	MCA	Neck pain	Fracture of odontoid process type III		-
7	Both	M	34	MCA	Cardiac arrest	Burst fracture of C4		-
8	Both	M	37	MCA	Monoparesis right arm	Fracture of right C7 transverse process and facet		-
9	Both	M	63	Fall	Paraparesis both arms	Inferior endplate fracture of C5		-
10	CT alone	F	39	Car accident	Neck pain	Fracture of C6 spinous process		-
11	Both	M	77	Car accident	Alteration of consciousness	Fracture of C5-6 spinous process		-
12	Both	F	81	Fall	Alteration of consciousness	Hangman's fracture		-
13	CT alone	M	23	MCA	Alteration of consciousness	Fracture odontoid process		-
14	Both	M	31	Fall from height	Quadriplegia	Burst Fracture of C6		-
15	Both	M	39	MCA	Alteration of consciousness	None	Fracture of left C7 transverse process	Fracture of left C7 transverse process
16	CT alone	M	81	Fall	Alteration of consciousness	Right occipital condyle fracture	Right occipital bone fracture	Right occipital bone fracture
17	Both	F	48	Car accident	Alteration of consciousness	Fracture of C7 spinous process	None	None
18	Both	F	74	Car accident	Neck pain	Fracture of C2 spinous process	None	None

Of all cases with documented clinical indication, the emergency physicians tended to order cervical spine CT properly according to NEXUS criteria or CCR. We imply that there is appropriate utilization under the ACR appropriateness criteria at least 91.3% at KCMH.

As for the remaining cases (8.7%), we cannot truly assume that these patients were sent for cervical spine CT in appropriately because some of these patients might have had clinical indication but the physicians failed to document it in the medical records. Therefore, we assume that there might be CT overutilization in some cases with no documented clinical indication from neither NEXUS nor CCR criteria.

Sheikh *et al*, reviewed all consecutive cervical spine radiographs and CTs performed in the emergent settings based on the established ACR appropriateness criteria. They found that 32.7% of the patients, who underwent cervical spine radiograph, as either the sole imaging modality or in conjunction with cervical spine CT (6.4%), were designated as "inappropriate".[1]

In our study, we did not recruit the patients who received only cervical spine radiographs. However, our findings revealed that 51% of the patients who received both cervical spine CT and radiographs, which was higher than the incidence from the report of Sheikh *et al*.[1] This could be a result of simultaneous ordering of radiographs and CT imaging examinations. Another possible reason of the higher incidence was that the 8th edition of ATLS guidelines was still widely used among emergency physicians during our study period, which ranged from November 2012 to October 2013. Unlike ACR appropriateness criteria and the 9th edition of ATLS, the 8th edition of ATLS mentioned that cervical spine radiography was the primary screening modality for all trauma patients who had midline neck pain, tenderness on palpation, neurological deficits referable to the cervical spine, or an altered level of consciousness or in whom intoxication was suspected.[9 – 11]

According to the current ACR appropriateness criteria, cervical spine radiographs is regarded as inappropriate imaging investigation for trauma in the adult. Thus, strict application of the ACR appropriateness criteria before cervical spine examination would have decreased unnecessary radiographs about 51% of patients who received cervical spine CT (76 studies fewer).

Our study is a retrospective study. This causes limitation in data collection, particularly clinical indication for cervical spine CT. As there are many single center researches on the same topic, to generalize this data for Thai population could be the second limitation.

Conclusion

This study shows that satisfied proportion of 91.3% of patients suspected of acute blunt cervical spine trauma at ER of KCMH were appropriately sent for cervical spine CT according to ACR appropriateness criteria. However, our study has failed to demonstrate the appropriateness in 8.7% of patient population due to incomplete medical records. Our study also implies that numbers of patients who underwent unsuitable bimodality imaging could have been reduced if ACR appropriateness criteria become more widely used.

Our expectation is that this study may result in improvement of applications of the ACR appropriateness criteria into practical use, which can reduce some CT over utilization and dramatically decrease the rate of unnecessary radiographs to clear the cervical spine, including optimizing radiation exposure and cost-effectiveness.

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