MISSED SPINAL INJURY: A SYSTEMATIC REVIEW

Hussein Abedel Zaher Abou Elghait, Ahmed Ibrahim Akar, Mohamed Ali Ahmed Ismail

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Abstract

Background: Advanced Trauma Life Support Course established primary and secondary trauma surveys to swiftly detect life-threatening and linked injuries (ATLS) The purpose of primary trauma surveys is to identify and reduce life-threatening injuries. A considerable proportion of injuries may evade secondary trauma surveys and go unnoticed until after the patient has left the emergency department. Generally speaking, a missed injury or a delayed diagnosis refers to an injury that was undiagnosed in the ED but recognised or undiagnosed upon subsequent admissions. Until proper and expert analysis of the cervical spine roentgenograms can be obtained, cervical spine precautions should be maintained, particularly in high-risk individuals. **Aim:** The aim of this study was to systematically review the literature to determine the incidence of missed and mismanaged injuries of the spinal cord, to identify factors contributing to a failure to recognize such injuries, and to assess how to avoid this failure. **Subject and methods:** This study is a systematic review, applied on humans to determine the incidence of missed injuries of the spinal cord and to assess how to avoid. **Results:** The most common cause for missed spinal injury was radiographic errors accounting for 46.4% of missed injuries. The most common method to reach the correct diagnosis was performing spinal MRI, representing 48.8%. **Conclusion:** Cervical spine precautions should be maintained, particularly in high-risk patients, until appropriate and expert review of the cervical spine roentgenograms can be obtained.

Key words: Missed Spinal Injury, Spinal trauma, tertiary survey.

Orthopedic Surgery Department, Faculty of Medicine, Al Azhar University, Egypt
Corresponding author: Mohamed Ali Ahmed Ismail
Email: Mohamedelakhras1@gmail.com, Mobile: 01005876307

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Introduction

Treatment of severely injured patients in emergency departments (EDs) is a challenge. To rapidly identify life-threatening and associated injuries, primary and secondary trauma surveys were introduced by the Advanced Trauma Life Support Course (ATLS) Primary trauma surveys are designed to identify and minimize life-threatening injuries, while secondary trauma surveys discover injuries using a meticulous physical examination and adjunct imaging studies Nevertheless, a substantial proportion of injuries may elude secondary trauma surveys, remaining undetected until after leaving the ED. An injury, undiagnosed in the ED but recognized or unrecognized in subsequent admissions, is customarily termed a missed injury or a delayed diagnosis. (1) Missed injuries is defined as an injury found after the initial complete patient assessment and diagnostic studies that was directly related to the traumatic event and was identified after first 24 hours following admission. Even though not frequently life-threatening, they may result in significant long-term disability. Patients with a decreased level of consciousness or head injury, with intubation/sedation or with alcohol or drug intoxication are unable to give a good history, cooperate with physical exam or identify sources of pain are the main risk factors for missed injuries. Other factors for missing an injury include Inadequate Clinical Assessment, Misinterpretation of Studies and Late Presentation of Observable Findings. Repeated assessments, both clinical and radiological, are mandatory to diminish this problem. In initial evaluation, one still has to treat the greatest threat to life before complete diagnosis of all injuries, but alertness to evolving injuries must remain in mind throughout the patient's hospital stay. (2)

In some patients the missed diagnosis of spinal injury led to mismanagement and a greater neurological deficit. Missed injuries occur with a remarkable degree of regularity in recognisable patterns, with the same or similar patterns of injuries being missed repeatedly in most reported series from around the globe. Most commonly there is a human factor involved in the process of the error.

The underlying factors increasing the risk of missing an injury in the trauma patient include:

- Life-threatening injury that changes priority of care
- Altered mental state or chemical neurological impairment
- Distracting major injury that distracts the focus of the treating team
- Need for emergency surgery precluding the completion of the primary and secondary survey (‘damage control’)
- Inexperience and stress of the medical and nursing team
- Inappropriate, or inadequate, access to or performance of imaging or laboratory examinations.[3]

The reasons for injuries being missed are complex and multifactorial. The high levels of diagnostic uncertainty associated with emergency patients, the need for time-dependent decision making, multiple care providers and surrounding distractions all increase the chances of missing injuries. Numerous handovers of care also result in loss of information. The quality of the system in which the provider is working also influences the risk of missing an injury. All of these factors lead to a lack of ‘dual-process’ thinking – an imbalance between protocol and common sense for example not following a particular line of investigation as per protocol because there are other distracting injuries or competing priorities.

Mis-triage occurs where older and very young patients are difficult to assess, when clinicians lack experience or skills, such as limited ATLS training and lack of trauma nursing skill, or in the presence of mainly junior staff, as is typical in many of the rural hospitals.

System issues include rural hospitals not referring appropriate patients timeously, or a delay in availability of radiology results and other investigations.

When all the above are viewed as intertwining concentric circles with multiple interplay, several factors can be identified, both internal and external, that affect error occurrence in a care system. These include patient factors, technological factors, the health worker’s physical and emotional state, ambient climatic and working conditions, the physical structure of the facility, social, legal and cultural influences and finally the quality of the hospital organisation .[4]

Patients and Methods

Criteria for considering studies for this review:

- **Type of Studies:** systematic review.
- **Types of participants:** Studies applied on humans.
- **Types of interventions:** to determine the incidence of missed injuries of the spinal cord and to assess how to avoid.
- **Types of outcome measures:**The outcome measures will considered:
- Incidence of missed and mismanaged injuries of the spinal cord.
- Identify factors contributing to a failure to recognize such injuries.
- Assess how to avoid missed injury.

Search strategy for identification of studies:
Relevant studies were identified using electronic searches of Scinece direct,PubMed,Scopus,Upto date, puplished in English.[2]The following key words were used to conduct the search: tertiary survey, trauma survey, traumatology, diagnostic errors of spinal injury, delay spinal diagnosis,missed spinal injuries how to avoid missed injury.

Methods of the review following the principle of Prisma chart:

➢ **Locating and selecting studies:** Abstracts of articles identified using the search strategy above will be viewed, and articles that appear to fulfill the inclusion criteria will be retrieved in full. Data on at least one of the outcome measures must be included in the study

➢ **Inclusion Criteria:**

✓Age :> 18 years.
✓English language of study.
✓Polytruma patiant.
✓Both Sexes.

➢ **Exclusion Criteria :**

☒Pathological fracture.
☒Incomplete outcome data.
☒Animal studies

Data extraction: The following data were extracted from the studies: title,
year of publication, country of study, study design, number of participants, age and gender of participants, injury severity score mechanism of trauma (blunt vs. penetrating), presence of an altered level of consciousness and admission to intensive care unit (ICU). The outcome parameters on missed injury rates and long-term outcomes were collectedwhen available.[2]

➢ .**Statistical consideration:**Outcomes from included reports will be combined using the Review Manager software manually screened for eligibility to be included.

Evidence of publication biaswill be thought using the funnel plot method:A funnel plot is a simple scatter plot of the intervention effect estimates from individual studies against some measure of each study’s size or precision

Results

Study Selection

The electronic search yielded 424 references from PubMed, 160 from Scopus, 156 from Embase, and

259 from Web of Science, with a total of 899 references from the four databases. After excluding 258 duplicates, 614 records remained for titles and abstract screening. We had 30 relevant articles eligible for full-text screening. Twenty articles were excluded according to the exclusion criteria. The manual search of references did not import any additional articles. Eventually, 10 articles fulfilled the predefined inclusion criteria and were ultimately included for analysis.

Study Characteristics

A total of 10 studies were selected for the current analysis, including a total of 2772 patients presenting with spinal trauma. Among the 2772 patients, 249 (9%) were defined as missed or delayed spinal injuries. Baseline characteristics of included studies are demonstrated in **Table 1**.

Table 1. Baseline Study Characteristics (All injuries = 2772, missed injuries = 249)

First Author	Year	Country	Design	No.	Age	Male	High Energy	Quality
Ravichandran	1982	UK	Retrospective	353	NA	15	NA	70%
Davis	1993	USA	Retrospective	740	35	26	32	85%
Demetri	2000	USA	Retrospective	292	NA	NA	NA	60%
Poonnoose	2002	UK	Retrospective	569	46.8	40	37	65%
Barrett	2006	USA	Prospective	224	NA	NA	NA	95%
Platzer	2006	Austria	Retrospective	367	46.6	11	NA	50%
Chhabra	2013	India	Retrospective	61	NA	NA	NA	65%
Nkusi	2015	Rwanda	Prospective	42	35.3	3	3	85%
Kanna	2016	India	Retrospective	84	NA	NA	NA	50%
Khatri	2016	India	Retrospective	40	NA	15	NA	70%

NA: data not available.

Publication year ranged from 1982 to 2016. The country of origin varied across the studies. Three studies were performed in the USA, another three were performed in India, two studies were conducted in the UK, one was conducted in Austria, and another one was conducted in the Republic of Rwanda.

As shown in **Figure 1**, all included studies were retrospective except for two prospective studies by Barrett et al, and Nkusi et al. **Table 2** demonstrates protocols used by different studies for data collection. Participants' age was reported in four studies, ranging from 35 to 47 years with a pooled average of 42.6 years. Gender distribution was reported in five studies, including a total of 95 (77%) males and 28 (23%) females (**Figure 2**). A male predominance was demonstrated among the study participants, where the percentage of male patients ranged from 61% to 100%.

Figure 1. Study Design

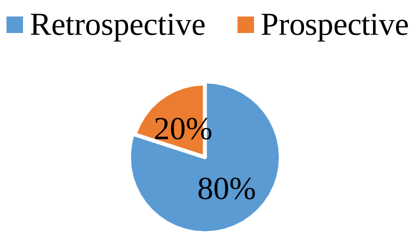


Figure 2. Gender Distribution

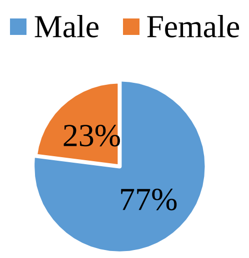


Table 2. Protocol of Data Collection in Included Studies

First Author	Patient Enrollment
Ravichandran	All patients admitted to one of the acute male wards in the National Spinal Injuries Centre over the decade ending in March 1981.
Davis	All trauma victims admitted to six trauma centers in the San Diego County Trauma System between 01/08/1985 to 2/28/1991.
Demetri	All blunt trauma patients injured in traffic accidents or falls with C-spine injuries admitted at the Los Angeles County and University of Southern California Medical Center between January of 1993 and December of 1997.
Poonnoose	All patients admitted for comprehensive management to the Regional Spinal Cord Injury Unit in Sheffield between April 1989 to April 1999.
Barrett	NEXUS study at 21 centers across the United States for all patients who sustained blunt trauma and underwent radiographic evaluation of their cervical spine.
Platzer	Patients with fractures and/or dislocations of the cervical spine that were admitted to the Level I trauma center at Vienna General Hospital, University of Vienna Medical School between January 1980, and December 2000.
Chhabra	SCI patients admitted to the spinal injury tertiary center between May 2009 and August 2011 for whom treatment could not be started till 4 weeks after the injury.
Nkusi	Patients with a missed or delayed cervical spine and/or cord injury treated at KFH-K from January 2012 to December 2012 retrieved from the hospital admission registry.
Kanna	Consecutive spinal injury patients (excluding pathological and osteoporotic fractures) treated between 2011 and 2013.
Khatri	Inpatient records of patients diagnosed with thoracolumbar traumatic injuries of more than three weeks duration between January 2008 to March 2014.

The mechanism of injury was reported in three studies. The majority of patients (80%) were exposed to a high energy trauma, including road traffic accidents, aircraft accidents, firearm injuries, and falling from heights, whereas only 18 (20%) patients were subjected to a low energy trauma. The severity of trauma was evaluated by Davis et al. using two scoring systems: injury severity score (ISS), and trauma score (TS). The mean ISS was 17 ± 2, and the mean TS was 13.7 ± 0.6.

Risk of Bias Within Studies

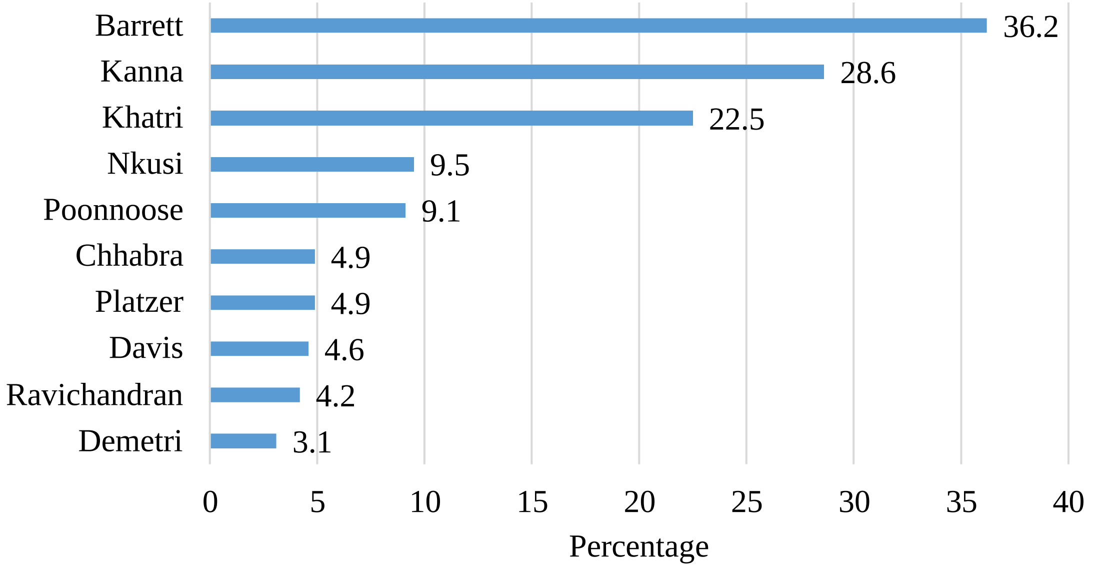
The methodological quality of the included articles was evaluated using the NIH's quality assessment tool for the observational studies. Subsequently, each study was given a score according to predefined quality criteria. The score ranges from 0% and 100% with the following categories: excellent (100%:75%), good (75%:50%), fair (50%:25%), and poor (25%:10%). The average score of the included studies was 70%, ranging from 50% to 95%. Three studies had excellent quality, five with good quality, two with fair quality, and none had poor quality, as previously demonstarted in **Table 1.**

Synthesis of Results

Incidence of Missed Spinal Injuries

In a total of 2772 trauma patients enrolled in this systematic review, 9% (249 patients) had either delayed or missed diagnosis of spinal injuries, ranging between 3.1% to 36.2%. The distribution of missed spinal injuries is illustrated in **Figure 3**.

Figure 3. Incidence of Missed Spinal Injury



Level of Missed Spinal Injuries

The level of missed injury was reported in eight studies, representing 222 patients with missed spinal injuries. The distribution of the location of missed injuries across studies is demonstrated in **Table 3**. The cervical spine was the level of missed injury in 190 (85.5%) patients, while the thoracolumbar spine injuries were missed in 32 (14.5%) patients. No cases of missed sacral spine injuries were reported.

Table 3. Level of Missed Spinal Injuries in Included Studies (No. missed injuries = 222)

First Author	No. Missed Injuries	Cervical Spine	Thoracolumbar Spine
Ravichandran	15	11 (73%)	4 (27%)
Davis	34	34 (100%)	-
Demetri	9	9 (100%)	-
Poonnoose	52	33 (63%)	19 (37%)
Barrett	81	81 (100%)	-
Platzer	18	18 (100%)	-
Nkusi	4	4 (100%)	-
Khatri	9	-	9 (100%)

The level of cervical spine injury was described in four studies, representing 89 patients (**Figure 4**). Upper cervical spine (C1-2) was involved in 20 (23%) patients. Lower cervical spine (C3-7) was involved in 67 (75%) patients. Both upper and lower cervical injuries were reported in two (2%) patients.

Figure 5. Pattern of Missed Injury

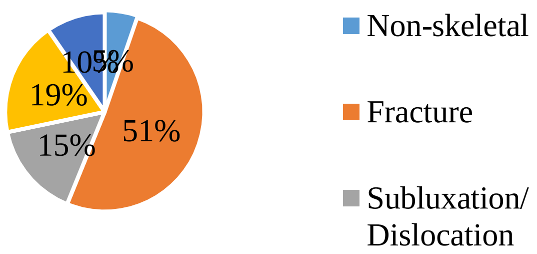
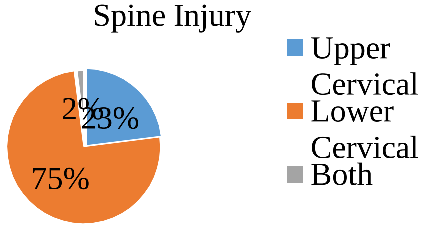


Figure 4. Level of Cervical Spine Injury



Pattern of Missed Spinal Injuries

Five different patterns of missed spinal injury were identified in seven studies, representing 222 patients (**Table 4**). As illustrated in **Figure 5**, non-skeletal (disco-ligamentous) injuries were reported in 16 (7.2%) patients, bony fractures were reported in 154 (69.3%) patients, and subluxation/dislocation injuries were reported in 47 (21.2%) patients. Fifty-six (25.2%) patients had multiple non-contiguous spinal injuries. In all, 29 (13.1%) injuries were deemed unstable.

Table 4. Pattern of Missed Spinal Injuries in Included Studies (No. missed injuries = 222)

First Author	No.	Non-skeletal	Fracture	Subluxation/ Dislocation	Non-contiguous	Unstable
Davis	34	-	29	10	1	24
Demetri	9	6	-	3	-	-
Poonnoose	52	6	45	1	8	-
Barrett	81	-	62	31	22	-
Platzer	18	3	15	-	1	-
Nkusi	4	1	3	2	-	-
Kanna	24	-	-	-	24	5

Causes of Missed Spinal Injury

As demonstrated in **Table 5**, nine studies, representing 168 patients, identified 12 different reasons for missed spinal injury.

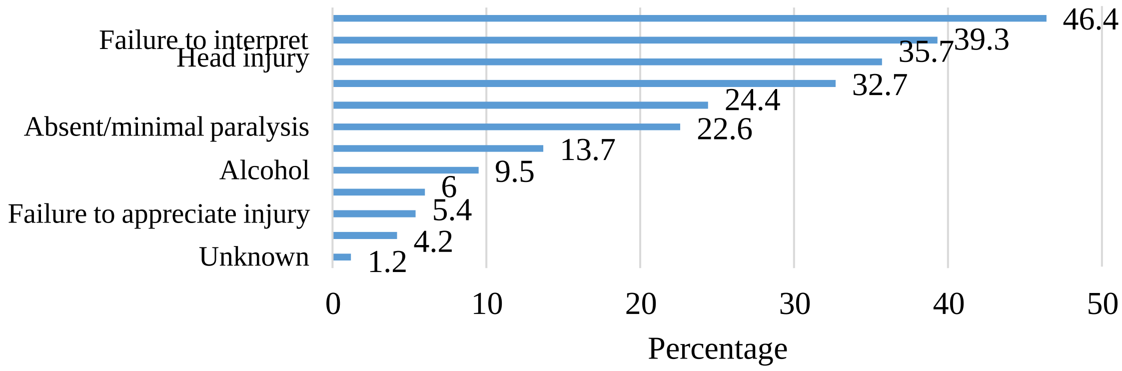
Table 5. Causes of Missed Spinal Injury in Included Studies (No. missed injuries = 168)

First Author	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫
Ravichandran	-	11	11	-	4	9	6	4	-	5	2	-
Davis	-	23	16	-	-	-	24	-	-		-	2
Demetri	-	-	-	-	3	-	3	1	-	1	2	-
Poonnoose	8	33	31	33	7	-	16	9	7	36	19	-
Platzer	1	9	8	8	-	-	5	2	-	6	-	-
Chhabra	-	-	-	-	-	-	1	-	-	2	-	-
Nkusi	1	2	-	-	-	-	-	-	-	1	-	-
Kanna	-	-	-	-	24	-	-	-	-	-	-	-
Khatri	-	-	-	-	-	-	-	-	-	9	-	-

①No radiograph ②Radiographic error ③Failure to interpret ④Failure to identify deficit ⑤Absent/minimal paralysis ⑥Failure to appreciate mechanism of injury ⑦Head injury ⑧Alcohol ⑨ Hysterical ⑩Multi-system injury ⑪Pre-existing spine pathology ⑫Unknown

The most common cause for missed spinal injury was radiographic errors accounting for 46.4% of missed injuries. Examples for radiographic errors were inadequate radiographic films, poor radiographic quality, imaging of wrong regions, or incomplete radiographic series. Failure of the examiners to interpret clear radiographic signs was reported in 39.3% cases, whereas radiographs were not requested in 6%.In 5.4%, diagnosis of spinal injuries was missed due to failure to appreciate the mechanism of injury. Distracting multi-system injuries were responsible for 35.7% of missed injuries. Disturbed consciousness level was reported in 32.7% due to head injuries, and in 9.5% due to alcohol intoxication. Nearly 4% were misdiagnosed as hysterical patients. Examiners failed to identify neurological deficits in 24.4%, whereas 22.6% had no or minimal paralysis at first presentation. In 13.7% cases, underlying spine pathology such as ankylosing spondylitis or spondylosis were possible causes for missed injuries. The cause of missed injury was not identified in 1.2%. Summary of different causes of missed spinal injury is illustrated in **Figure 6**.

Figure 6. Causes of Missed Spinal Injury



Correct Diagnosis

The time lapse between the onset of injury and the time to reach the correct diagnosis ranged between 10 hours to 40 days. As demonstrated in **Table 6**, eight studies, representing 246 patients, reported how correct diagnosis of missed injuries was made.

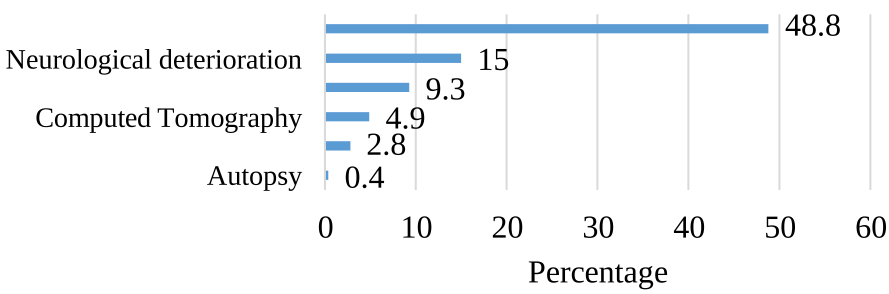
Table 6. Correct Diagnosis in Included Studies (No. missed injuries = 246)

	Time Lapse	Senior Consultation	Neurological Deterioration / Persistent Symptoms	X-ray	CT	MRI	Autopsy
Ravichandran	1 – 21	-	4	2	-	-	-
Davis	1 – 30	-	15	14	2	1	-
Demetri	NA	-	-	-	3	6	-
Poonnoose	0.4 – 42	-	-	-	-	6	-
Barrett	NA	-	-	-	-	81	-
Platzer	1 – 21	7	14	7	4	1	1
Nkusi	1 – 40	-	4	-	3	1	-
Kanna	NA	-	-	-	-	24	-

NA: data not available; Time lapse is presented in days.

The most common method to reach the correct diagnosis was performing spinal MRI, representing 48.8%. Deterioration of neurological status or persistence of neck pain were responsible for diagnosis in 15%. Complete series of adequate x-rays were required in 9.3%, whereas CT scan was necessary to reach diagnosis in 4.9%. In 2.8%, correct diagnosis was made after consultation of senior surgeons. One case was diagnosed by autopsy. Summary of methods reported to reach correct diagnosis is illustrated in **Figure 7**.

Figure 7. Correct Diagnosis of Missed Spinal Injury



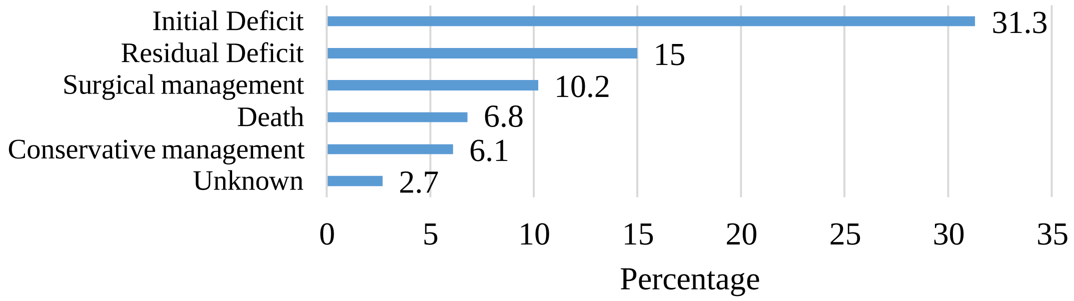
Outcomes of Missed Spinal Injuries

As demonstrated in **Table 7**, six studies reported on outcomes of missed spinal injuries. The overall mortality rate was 6.8%. Initial paralysis was reported in 31.3%, whereas only 15% had permanent neurological deficit. In 6.1%, conservative treatment was adopted, while surgical intervention was required in 10.2%. Ravichandran et al. reported four cases with unknown outcomes (**Figure 8**).

Table 7. Outcomes of Missed Spinal Injuries in Included Studies (No. missed injuries = 147)

	Death	Initial Deficit	Residual Deficit	Surgical	Conservative	Unknown
Ravichandran	-	11	2	-	-	4
Davis	2	-	8	-	-	-
Poonnoose	6	26	9	-	-	-
Platzer	2	6	2	7	8	-
Nkusi	-	3	1	3	1	-
Kanna	-	-	-	5	-	-

Figure 8. Outcomes of Missed Spinal Injury



Discussion

Traumatic injuries to the spine can be common in the setting of blunt trauma and delayed diagnosis can have a deleterious effect on patients' health. Spine trauma patients, especially poly-trauma patients, can present unique challenges to the spine surgeon. Spine fractures that require surgical intervention, should be managed promptly to improve or prevent neurologic deficit . [5]

Spine trauma can be one of the most debilitating ailments. It affects not only an individual's health but also creates an enormous burden on the family and society. Good clinical and radiological evaluations are important to plan management and thereby optimize the outcome. Plain radiographs have several limitations, including the non-visualization of low-contrast structures with an acceptable amount of radiation exposure. The introduction of CT was a major imaging advancement. CT is more sensitive to density variations than ordinary X-rays and is faster. Over the last decade, a massive shift has been observed in the imaging assessment of spine trauma. For suspected spinal injury, for example, the assessment has become prompter and more precise by shifting from X-rays to CT. Furthermore, the advent of MRI has helped provide better visualization of the spinal cord and soft tissue structures such as ligaments, disk, and blood vessels than was possible with CT or X-rays. Accessibility to diagnostic imaging is better in developed countries when compared to less and least developed countries. In these countries with large patient populations, low-cost diagnostic imaging modality such as X-rays is more frequently used compared to capital intensive equipment such as CT and MRI (2). Failure to recognize evidence of spinal column injuries because of radiographic or radiodiagnostic errors has been highlighted in several recent articles. These reports included patients with and without associated neurologic injuries.[6] Studies have documented better outcomes for patients in whom rehabilitation is initiated early, especially, in an organized multidisciplinary spinal cord injury (SCI) care system. These studies have been conducted only in developed countries. In emerging countries, the scenario is somewhat different in that not only do spinal injured often present quite late (even months or years after injury) to the definitive center, but they have also often had either inadequate or no treatment and there is often an unsupervised period at home. [7]

The main aim of this study was to systematically review the literature to determine the incidence of missed and mismanaged injuries of the spinal cord, to identify factors contributing to a failure to recognize such injuries, and to assess how to avoid this failure.

This systematic review study included total of 10 studies were selected for the current analysis, including a total of 2772 patients presenting with spinal trauma. Among the 2772 patients, 249 (9%) were defined as missed or delayed spinal injuries.

The main results of this study were as following:

As regard demographic data, participants' age was reported in four studies, ranging from 35 to 47 years with a pooled average of 42.6 years. Gender distribution was reported in five studies, including a total of 95 (77%) males and 28 (23%) females. A male predominance was demonstrated among the study participants, where the percentage of male patients ranged from 61% to 100%.

Our results were supported by study of **Chhabra & Arora,** [8] as they reported that the majority of them were males (93%) with mean age 32.47±12.74 years.

Also, in the study of **Poonnoose et al.,** [9]**,** there were 40 men with a mean age of 43.2 years (range, 17–81 years) in whom the spinal cord injury was initially missed. The average age of the 12 women was 59 years (range, 25–92 years).

The present study showed that as regard the mechanism of injury was reported in three studies. The majority of patients (80%) were exposed to a high energy trauma, including road traffic accidents, aircraft accidents, firearm injuries, and falling from heights, whereas only 18 (20%) patients were subjected to a low energy trauma. The severity of trauma was evaluated by Davis et al. using two scoring systems: injury severity score (ISS), and trauma score (TS). The mean ISS was 17 ± 2, and the mean TS was 13.7 ± 0.6.

In accordance with our results the study of **Platzer et al.,** [10] as they reported that clinical records showed several mechanisms of injury. The injuries resulted from car or motorcycle accidents in 44%, falls in 22%, jumps into shallow water in 15%, varioussports activities in 8%, scuffles in 1%, and from other mechanisms in 9%. Fifty-three patients (14%) came in walking, 138 patients (38%) were brought in by ambulance, 66 patients (18%) by emergency car or emergency helicopter, and 110 patients (30%) were transferred from other hospitals.

Similarly, **Davis et al.,** [11] demonstrated that the most common mechanism among their studied group was vehicle accidents followed by bicycle crash, motorcycle crash, fall and airplane crash.

The current study showed that as regard incidence of Missed Spinal Injuries: in a total of 2772 trauma patients enrolled in this systematic review, 9% (249 patients) had either delayed or missed diagnosis of spinal injuries, ranging between 3.1% to 36.2%.

Our results were in line with study of **Barrett et al.,** [12] as they reported that eighty-one of these 224 patients (36.2%; 95% confidence interval [CI] 29.9% to 42.8%) had at least 1 secondary injury that was not identified on plain radiography.

Also, in the study of **Kanna et al.,** [13]**,** 28.6% of their studied cases had missed spinal injuries.

Furthermore, **Khatri et al.,** [14] revealed that missed injury cases were the patients with associated head injury or polytrauma. In these cases the diagnosis was delayed due to presence of other injuries. The delay in definitive treatment was three to six weeks in 22 patients, between six to 12 weeks in 10 patients and more than 12 weeks in eight patients.

Moreover, in the study of **Nkusi et al.,** [15]**,** 9.5% of their studied cases were missed spinal injuries.

In the study in our hands, as regard level of Missed Spinal Injuries*;* the level of missed injury was reported in eight studies, representing 222 patients with missed spinal injuries. The cervical spine was the level of missed injury in 190 (85.5%) patients, while the thoracolumbar spine injuries were missed in 32 (14.5%) patients. No cases of missed sacral spine injuries were reported.The level of cervical spine injury was described in four studies, representing 89 patients. Upper cervical spine (C1-2) was involved in 20 (23%) patients. Lower cervical spine (C3-7) was involved in 67 (75%) patients. Both upper and lower cervical injuries were reported in two (2%) patients.

Our results were supported by study of **Kanna et al.,** [13]**,** as they reported that the primary injuries in patients with multi-level injuries were distributed in the cervical region in 37 patients (38.9 %), thoracolumbar region in 26 patients (27.4 %), lumbosacral region in 13 patients (13.7 %) and thoracic region in 19 patients (20 %).

Also, in the study of **Nkusi et al.,** [15]**,** they reported a series of cases of missed or delayed cervical spine injuries treated at a tertiary level hospital, King Faisal Hospital, Kigali (KFH, K), and identifies the causes of the delayed or missed diagnosis. We are focusing on cervical spine injuries because we have observed that cervical spine injuries were more commonly missed, were more devastating in terms of neurological deficits and were more commonly associated with head injuries.

Furthermore, **Platzer et al.,** [10] revealed that in all, 140 patients (38%) sustained an injury of the upper cervical spine (C1/C2), 212 patients (58%) an injury of the lower cervical spine (C3–C7), and 15 patients (4%) suffered from a combined injury of the upper and lower cervical spine. Clinical records showed several mechanisms of injury.The missed injuries of the upper cervical spine consisted of five fractures of the odontoid process, one Jefferson fracture, and a slightly displaced fracture of C2. The missed injuries of the lower cervical spine comprised a fracture of C4, two displaced fractures of C5, two fractures of C6, one displaced fracture of C7, and three discoligamentous instabilities. In the two patients with combined injuries of the upper and lower cervical spine level, once a fracture of C2 and C3 was missed and once a fracture of the atlas and C5 was failed to diagnose.

The present study showed that as regard Pattern of Missed Spinal Injuries: five different patterns of missed spinal injury were identified in seven studies, representing 222 patients. Non-skeletal (disco-ligamentous) injuries were reported in 16 (7.2%) patients, bony fractures were reported in 154 (69.3%) patients, and subluxation/dislocation injuries were reported in 47 (21.2%) patients. Fifty-six (25.2%) patients had multiple non-contiguous spinal injuries. In all, 29 (13.1%) injuries were deemed unstable.

Our results were supported by study of **Kanna et al., [13],** as they reported that ninety-five (19.62 %) patients had multi-level injuries. Of these, 86 (17.76 %) patients had non-contiguous injuries and 9 (1.8 %) patients had contiguous injuries. Amongst non-contiguous injury, 71 injuries (14.67 %) were inter-regional, and 15 injuries (3.09 %) were intra-regional.

Also, in the study of **Khatri et al., [14]**, the majority of the injuries were classified as burst fractures in 20 cases followed by fracture dislocations in 17 cases. There was single case each of traumatic spondylolisthesis, spondyloptosis and soft tissue chance fracture.

The current study showed that as regard causes of missed spinal injury: the most common cause for missed spinal injury was radiographic errors accounting for 46.4% of missed injuries. Examples for radiographic errors were inadequate radiographic films, poor radiographic quality, imaging of wrong regions, or incomplete radiographic series. Failure of the examiners to interpret clear radiographic signs was reported in 39.3% cases, whereas radiographs were not requested in 6%. In 5.4%, diagnosis of spinal injuries was missed due to failure to appreciate the mechanism of injury. Distracting multi-system injuries were responsible for 35.7% of missed injuries. Disturbed consciousness level was reported in 32.7% due to head injuries, and in 9.5% due to alcohol intoxication. Nearly 4% were misdiagnosed as hysterical patients. Examiners failed to identify neurological deficits in 24.4%, whereas 22.6% had no or minimal paralysis at first presentation. In 13.7% cases, underlying spine pathology such as ankylosing spondylitis or spondylosis were possible causes for missed injuries. The cause of missed injury was not identified in 1.2%.

Regarding Correct Diagnosis*:* the time lapse between the onset of injury and the time to reach the correct diagnosis ranged between 10 hours to 40 days. The most common method to reach the correct diagnosis was performing spinal MRI, representing 48.8%. Deterioration of neurological status or persistence of neck pain were responsible for diagnosis in 15%. Complete series of adequate x-rays were required in 9.3%, whereas CT scan was necessary to reach diagnosis in 4.9%. In 2.8%, correct diagnosis was made after consultation of senior surgeons. One case was diagnosed by autopsy.

Our results were in line with study of **Platzer et al., [10]** as they reported that in eight cases (44%), delayed diagnosis was found to be the result of a misinterpretation of the standard radiographs. Junior staff responsible for initial radiologic examination failed to diagnose the injuries. In six cases, correct diagnosis was made later on from the standard radiographs by more experienced senior surgeons following the control mechanism of the unit. Experienced staff evaluated all plain radiographs secondarily within 24 hours. In two cases, the injury was diagnosed after performing a CT scan because of continuous neck pain. In five cases (28%), incomplete sets of radiographs were responsible for delayed diagnosis. Three discoligamentous injuries were missed because no functional flexion/ extension views were performed. One of the patients had an isolated discoligamentous injury. He was polytraumatized and unconscious as a result of a severe brain injury during primary examination. Clearing the cervical spine with complete sets of standard radiographs and CT scan did not show the extent of the injury. After regaining consciousness, the patient had a complete tetraplegia. Functional flexion/extension views and MRI were ordered showing the discoligamentous injury.

In the previous study [10]; the other two cases with incomplete sets of radiographs, fractures were missed because only a lateral view of the cervical spine was performed during initial evaluation. Both patients were polytraumatized and primary examination focused on other severe injuries. Correct diagnosis was made after performing complete sets of standard radiographs in one case and by autopsy in the other case. In four cases (22%), the injury was missed because inadequate radiographs did not show the level of the injury. All four delayed diagnosis occurred at the lower cervical spine level. Performing proper x-ray views was difficult because of degenerative spine disease, severe neck pain, or altered mental state. In two cases, correct diagnosis was made by a CT scan, in one case by tomography, and in another case after repeating standard radiographs. In one case (6%) of delayed diagnosis, the injury was missed because the treating surgeon did not see the radiographs. The patient returned later on with increasing neck pain. Correct diagnosis could then be made by another surgeon who checked the initial radiographs.

Also, in the study of **Poonnoose et al., [9],** a major cause for the delay in diagnosis seems to be related to a failure to appreciate radiologic signs. Initial radiographs were of poor quality in 18 of the 52 cases. The entire region was not visualized adequately in 11 of 52 instances. In four cases, radiographs of uninjured regions were requested. Surprisingly, in 10 of 52 of the radiographs, an obvious fracture was missed. Another 11 of 52 lesions were missed because of failure to interpret facet joint malalignment. Initial radiographs of 10 (10 of 52) patients who developed tetraplegia showed evidence of increased prevertebral soft tissue space, suggestive of hematoma. In these patients, a spinal column lesion could have been suspected if closer attention was given to the presence of increased prevertebral soft tissue shadow. Six of the patients in whom the paralysis was missed had no obvious vertebral injury on the routine radiographs, and magnetic resonance imaging (MRI) scans were required to confirm cord damage. Spondylitic changes on the cervical spine contributed to the difficulty inthe diagnosis in 14 patients. Five of the patients had ankylosing spondylitis, and this probably led to a difficulty in obtaining and assessing the radiograph. In eight patients, no radiograph was taken when the patient presented with the SCI, since the treating physician did not feel it was warranted. There was one patient who was first seen in Turkey, whose initial radiographic details were not available. Radiodiagnostic difficulties arose in most instances as a result of a combination of more than one of the factors listed above.

While in the study of **Khatri et al., [14]**, inadequate primary treatment at the first contact hospital (45% followed by late presentation (38%) and missed injury (17%) were the major reasons for the neglected traumatic injuries in thoracolumbar spine.

Whereas in the study of **Chhabra & Arora, [8]**, various specific causes were grouped under three general causes. Premature discharge in first admission with inadequate or no rehabilitation (52.5%) and late presentation by the patient (42.6%) were the major general causes, whereas overlooked diagnosis accounted for only 4.9%.The duration of neglect (injury–admission interval) was 4–8 weeks in 29.5%, 8–24 weeks in 21.3% and more than 24 weeks in 49.2%

In the study in our hands, as regard outcomes of Missed Spinal Injuries, six studies reported on outcomes of missed spinal injuries. The overall mortality rate was 6.8%. Initial paralysis was reported in 31.3%, whereas only 15% had permanent neurological deficit. In 6.1%, conservative treatment was adopted, while surgical intervention was required in 10.2%. Ravichandran et al. reported four cases with unknown outcomes.

Furthermore, **Poonnoose et al., [9],** stated that in 26 of 52 patients (50%), mismanagement of SCI resulted in neurologic deterioration. In seven of these patients, the neurologic deficit at the time of initial presentation to the accident and emergency unit was minimal. The remaining 19 had significant neurologic deficit, which deteriorated after mismanagement. In nine patients, mismanagement caused the neurology to deteriorate to complete paralysis. Six patients died as a direct result of the delay in diagnosis. Eight patients had more than one vertebral fracture. Even though one of the vertebral column injuries was initially recognized, the second injury remained unrecognized in these patients, resulting in additional neurologic disability.

Spinal trauma involves a combination of injuries to the vertebral column, spinal cord, intervertebral discs and the supporting ligaments. Most classification systems of spinal injury and treatment decisions have been based on injuries to the vertebral bones as observed in radiographs and CT. However, with the advent of MRI, the evaluation of spinal trauma patient has changed tremendously. MRI enables detailed and thorough assessment of the spinal cord, paraspinal soft tissues, integrity of the intervertebral discs and posterior ligamentous complexes. Though MRI does not offer any advantage over plain radiography or CT in the evaluation of osseous injury of the vertebral column, one major advantage of MRI is our ability to acquire whole spine MRI sequence with no necessity for repositioning. This can pick up non-contiguous spinal fractures without risks of radiation and missing injuries in radiographs. Any acute cortical fracture will display marrow signal abnormality that is easily picked up in T2 fat saturation or suppression sequences. MRI is also sensitive to demonstrate compressive injury to the marrow elements even without evidence of cortical breaks which is not detected in X-ray or CT [16].

Conclusion

Blunt trauma can cause traumatic spine injuries, and delayed diagnosis can harm patients. Spine trauma patients, especially polytrauma patients, may offer distinct challenges. There are some recognized useful protocol for the evaluation and diagnosis of spine injuries .

A protocol for protection of the entire spine must be in place in all hospitals managing trauma patients at risk of spinal injury. This protection must be maintained from arrival until appropriate examination or investigations are completed and the spine cleared of injury.

- Documentation of the neurological status must be made in all at-risk patients; any sign of spinal cord injury mandates urgent scanning.
- A clinical examination of the whole spine should be documented.
- If it is anticipated a patient will remain unconscious, unassessable or unreliable for clinical examination, radiological spinal clearance imaging should be undertaken.
- For the cervical spine, the appropriate standard is a thin slice (2-3mm) helical CT scan from the base of the skull to at least T1 with both sagittal and coronal reconstructions; extending that scan to T4/5 overcomes the difficulties of imaging the upper thoracic spine.
- It is recommended that this cervical spine CT scan be undertaken as a routine with the first CT brain scan in all head-injured patients who have an altered level of consciousness.
- The remaining thoracic and lumbar spine may be adequately imaged either by AP and lateral plain radiographs or by sagittal and coronal reformatting of helical CT scans of the chest, abdomen and pelvis undertaken as part of a modern CT trauma series (<5mm slices).
- A senior must report spinal clearance images prior to withdrawal of spinal protection precautions.
- If a spinal injury is detected, a neurological assessment must be made, even if incomplete, and repeated regularly prior to urgent transfer to an appropriate spinal injury service.
- MRI is the urgent investigation of choice for spinal cord injury

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