

## Original Research Article

# A tailored protocol in management of penetrating neck injuries: experience at a level 1 trauma centre

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## ABSTRACT

**Background:** The management of penetrating neck injuries (PNIs) evolved markedly over last year's towards more conservative approaches. Recent improvements in imaging modalities as multi-detector CT-angiography (MDCT-A) produced a paradigmatic shift towards 'no-zone' approach. In this study, we adopted a tailored protocol to deal with such injuries with less dependency on zone classification.

**Methods:** This prospective study included patients with PNIs from February 2012 to January 2014. Unstable patients and patients with hard signs in zone-II were managed by immediate exploration. Patients with hard signs in zones-I and III had MDCT-A to check feasibility of endovascular intervention. However, all patients with soft signs and asymptomatic patients underwent MDCT-A regardless the zone affected to determine the need for therapeutic intervention. Complementary investigations were added in some cases with equivocal MDCT-A results.

**Results:** Our study included 85 patients. Majority were males (94%; n=80) with mean age 27±4. Stabs were the main causative injury (51%; n=43). 63 (74%) patients were stable; with majority (64%; n=40/63) were symptomatic (18 presented with hard signs and 22 presented with soft signs). 53 (62%) patients had MDCT-A with sensitivity, specificity of 77%, 97% respectively and significant p value <0.05. After applying this protocol, we avoided 37% (31/85) non-therapeutic neck exploration, with only 4 (7.4%) negative cases on exploration. We experienced no missed injuries in the conservative group, yet 2 (3.7%) missed nerve injuries were encountered in intervention group.

**Conclusions:** Zones-classification is losing popularity nowadays and shouldn't be the cornerstone of the new management protocols in PNIs. This selective tailored approach can be effectively used in management of PNIs. It avoids missed injuries and unnecessary explorations significantly.

**Keywords:** Penetrating neck injuries, Multi-detector CT-angiography, Cervical trauma, Neck zones

## INTRODUCTION

Penetrating neck injury (PNIs) represents 5-10% of all trauma cases with a mortality rate of 5-10% in many studies.<sup>1-3</sup> The management of PNIs is considered difficult because of the complex anatomy, immediate proximity of vital structures and the potential for rapid haemodynamic and airway deterioration. Therefore, a well-prepared trauma team using an appropriate tailored management protocol becomes essential to improve the outcomes.

The traditional management of PNIs which focused on mandatory exploration was challenged over last decade. The data from high volume trauma centres is now moving to the selective management protocols.<sup>4-6</sup> Despite the absence of international guidelines, most recent published data advocated the use of clinical examination and imaging to decide properly the need for neck exploration.<sup>7</sup>

Recently, incorporation of multidetector computed tomographic angiography (MDCT-A) into the diagnostic

armamentarium for penetrating neck trauma led to a marked change in the management protocols. This examination showed a high accuracy in detection of injuries particularly vascular injuries. However, the number of published protocols which rely on MDCT-A are still scarce.<sup>4,8-11</sup>

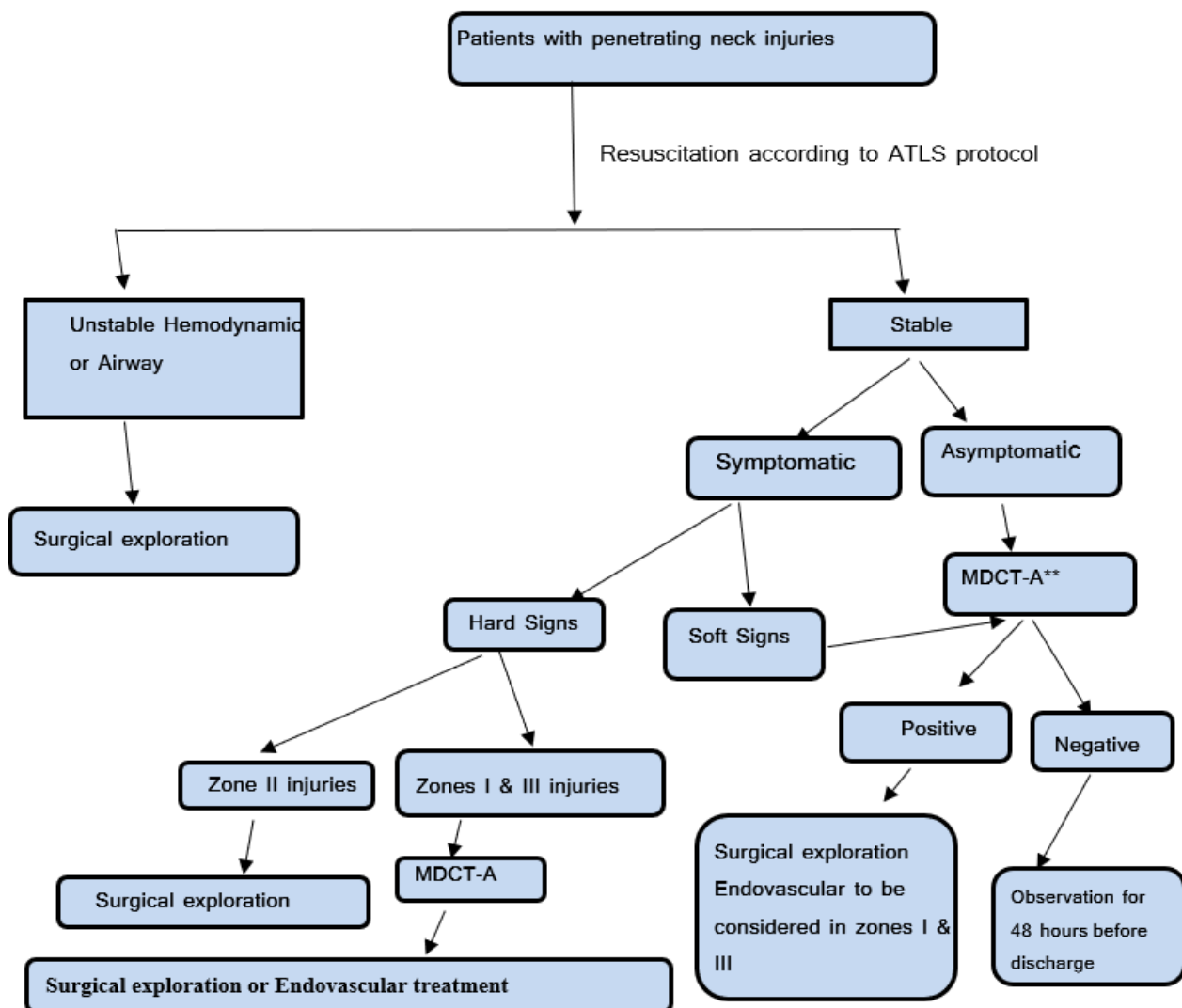
In our institution, we have a high flow of trauma cases (nearly 9,000-12,000 cases/year). PNIs represent about 0.1-0.4% of all trauma cases (nearly 40-50 cases/year). This is close to most of high trauma centres which receive around 20 PNI cases/year at least.<sup>2,5,13</sup>

In this study, we established a tailored protocol in the management of PNIs. It depends on the use of proper physical examination and MDCT-A to determine the need for surgical intervention. We aimed at evaluating the feasibility of applying this protocol in management of

PNIs. The primary outcome of our study was the percentage of missed injuries. The secondary outcomes were the percentage of non-therapeutic explorations and the mortality rate.

## METHODS

This is a prospective study of all patients with PNIs who presented to our emergency department from February 2012 to January 2014. Patients with superficial injuries (not breaching platysma) and blunt injuries were excluded. We defined the neck zones according to the traditional neck zones classification.<sup>14</sup> Ethical approval was obtained prior to the study from our local ethical committee for research at our institution. Informed consent was obtained priorly from patients to be involved in this research work. Figure 1 shows the flowchart of our tailored protocol.



**Figure 1: Flowchart of our tailored protocol in management of penetrating neck injuries.**

\*\* Complementary investigations were done in cases of equivocal MDCT-A results only: Duplex for suspected zone II vascular injuries, conventional angiography for suspected zones I & III vascular injuries, Contrast swallow test for suspected pharyngeal or oesophageal injuries and bronchoscope for suspected airway injuries.

All patients were resuscitated initially using ATLS protocol then management was directed according to our protocol.<sup>15</sup> Unstable patients were rushed to immediate surgical exploration without any prior imaging. We set the instability criteria according to ATLS guidance including hemodynamic and airway instability.<sup>15</sup>

Stable patients were classified according to a comprehensive clinical examination into either symptomatic or asymptomatic. Symptomatic group were further divided according to the presence of hard or soft signs.<sup>6,16</sup>

Presence of hard signs prompted surgical intervention, but MDCT-A was performed prior to intervention in patients with zones I and III injuries to determine the feasibility of endovascular treatment.

All patients with soft signs and asymptomatic patients underwent MDCT-A to assess the presence of any internal injuries. We didn't use additional investigations routinely for all cases in our protocol. However, we relied on the clinical examination and CT scan results to guide the need for further investigations. We used complementary duplex in zone-II injuries with suspected vascular injuries. Furthermore, we used complementary angiography in zones I and III injuries where endovascular management seemed to be feasible. Supplementary contrast swallow test and bronchoscope were done if aerodigestive injuries were suspected.

All patients were observed for at least 48 hours prior to discharge. Clavien-Dindo (CD) classification was used for post-operative complications. Follow up of all patients was done at 4 weeks and 3 months post discharge at the surgical outpatient clinic in our institution.

Data set was analysed to evaluate the outcomes and the efficiency of the protocol. Accuracy of the presenting clinical signs, MDCT-A and other used investigations were assessed. Accuracy was represented using the terms of sensitivity, specificity, positive and negative predictive values. Statistical analysis was done by SPSS v15 (SPSS Inc., IL, USA). Comparison was performed using Chi-square ( $\chi^2$ ) test. P value <0.05 was considered statistically significant.

## RESULTS

During the study period, 85 patients presented with penetrating neck injuries and were included in our study. They represented 0.4% of total trauma patients admitted to our institution during the study period. The details of demographic data, mode of injury and distribution of injured zones are shown in Table 1.

### Clinical presentations

Our patient cohort comprised 63 stable patients (63/85;74%). Twenty-three patients (23/63;37%) were

asymptomatic and 40 patients (40/63;63%) showed established signs. Among the symptomatic patients; 18 (45%) presented with hard signs and 22 (55%) presented with soft signs.

Vascular presentation was the most common presentation and was seen in 31 patients (31/40;78%); while 9 patients (9/40;22%) presented with aero-digestive signs. Table 2 displays the detailed data of clinical presentations.

### Imaging modalities (Table 1)

Fifty-Three patients (53/85;62%) underwent investigations while the rest had urgent surgical intervention with no prior imaging. All the 53 patients had MDCT on presentation; 15 (28%) patients were positive while 38 (72%) patients were negative. Only one patient (2%) was false positive, while four patients (7%) were false negative on exploration. Three of the four false negative patients had bleeding from unnamed muscular vessels, while the other one was partial tear of IJV which repaired by direct sutures. Therefore, MDCT-A was accurate in 48/53 (91%) resulted in a significant p value <0.05.

Through the 25 (25/53;47%) patients who had duplex; 6 (24%) cases only were positive with one (4%) false positive case and no missed injuries. Thus, a significant p value <0.05 was encountered.

Six (6/53;11%) patients had angiography; 2 didn't need further surgical intervention, however, 3 were managed by endovascular technique and one patient needed open intervention. Contrast swallow studies were required in 13 (13/53;25%) cases with suspected digestive injuries but no injuries were detected and all were true negative. Bronchoscope was used in 3 (3/53;6%) patients with confirmation of two injuries.

### Lines of management

After applying our protocol, we managed to conserve on 31 (37%) patients, while 54 (63%) needed surgical intervention with 4 negative cases (7.4%) on exploration. Among the operative group, 3 (6%) patients were managed by endovascular techniques. There were 65 injuries detected in 50 patients throughout the study. The details of the injuries and the operative management are described in Table 3.

### Outcomes and follow up data

There were no missed injuries in the conservative group. However, we encountered 2 (2/54;3.7%) missed injuries in the operative group, both were nerve injuries. One case of brachial plexus injury and another case with phrenic nerve injury. Both cases had vascular injuries which were controlled during surgical exploration. Both missed injuries were detected on the second day post-surgery by

clinical examination. Fluoroscopy was used in addition for the phrenic nerve injury case.

**Table 1: Data for demographics, injury details, investigations and management lines.**

Variables	Number of patients (%)
<b>Gender</b>	
Males	80 (94)
Females	5 (6)
<b>Mean age in years (±SD):</b>	27±4
<b>Mode of trauma</b>	
Stab injury	43 (51)
Shotgun injury	24 (28)
Bullet injury	12 (14)
Road traffic accident	6 (7)
<b>Zones of injury</b>	
Zone I	16 (19)
Zone II	44 (52)
Zone III	13 (15)
Multiple	12 (14)
<b>Investigations done</b>	
MDCT-A	53 (62)
Duplex	25 (47)
Conventional angiography	6 (11)
Contrast swallow	13 (25)
Bronchoscope	3 (6)
<b>Lines of management</b>	
Conservative treatment	31 (37)
Operative treatment	54 (63)
Open approach	51 (94)
Endovascular approach	3 (6)

**Table 2: Details of clinical presentations and related positive injuries of all patients included in the study.**

Clinical presentation	Number of patients (%)	Number of positive injuries (%)
<b>Unstable patients</b>		
Patients	22 (26)	22 (100)
Hemodynamic unstable	19 (86)	19 (100)
Airway unstable (stridor)	3 (14)	3 (100)
<b>Stable patients</b>		
Patients	63 (74)	28 (44)
Asymptomatic	23 (37)	1 (4)
Symptomatic	40 (63)	27 (68)
Hard signs	18 (45)	17 (94)
<b>Vascular</b>		
Active bleeding	6 (33)	6 (100)
Expanding or pulsating hematoma	6 (33)	5 (83)
Thrill	4 (23)	4 (100)
<b>Aerodigestive</b>		
Saliva from the wound	2 (11)	2 (100)
Soft signs	22 (55)	10 (45)
<b>Vascular</b>		
Stable hematoma	11 (50)	4 (36)
History of bleeding (witnessed by paramedics)	4 (18)	3 (75)
<b>Aerodigestive</b>		
Surgical emphysema	5 (23)	1 (20)
Air in imaging	2 (9)	2 (100)

**Table 3: Details of main injuries and treatment modalities.**

Sites of injury	Number (%)	Type of injury	Management
<b>Common carotid artery</b>	<b>16 (25)</b>	Complete or partial tear (n=14)	Interposition graft (n=8), ligation (n=1), patch (n=1), direct sutures (n=4)
		Pseudoaneurysm (n=1)	Covered stent (endovascular)
		AV fistula* (n=1)	Interposition graft (synthetic)
<b>Internal carotid artery</b>	<b>1 (2)</b>	Complete cut	Ligation
<b>External carotid artery and branches</b>	<b>10 (15)</b>	Complete cut	Ligation
<b>Subclavian vessels</b>	<b>7 (11)</b>	Artery: Partial or complete tear (n=4), Pseudoaneurysm (n=2)	Direct sutures (n=1), ligation (n=1), Interposition graft (n=2)
		Vein: partial tear (n=1)	Covered stents (endovascular) patch
<b>Subclavian artery branches</b>	<b>2 (3)</b>	Vertebral artery: complete tear (n=1)	Ligation
		Thyrocervical trunk: complete tear (n=1)	
<b>Internal jugular vein</b>	<b>11 (17)</b>	Partial or complete tear (n=10)	Direct sutures (n=5), ligation (n=5)
		AV Fistula* (n=1)	ligation
<b>Pharynx/oesophagus</b>	<b>8 (12)</b>	Partial tear	Direct sutures (single layer)

Continued.

Sites of injury	Number (%)	Type of injury	Management
Larynx/trachea	6 (9)	Partial tear	Direct sutures (single layer) (n=3) tracheostomy (n=3)
Nerve injuries	4 (6)	Recurrent laryngeal nerve	Conservative
		Phrenic nerve	
		Facial nerve	Delayed surgical repair
		Brachial plexus (C-5 root)	

\*AV fistula: arteriovenous fistula.

The mean of hospital stay was 5 ( $\pm 6$ ) days. There were 3 (3/54;6%) cases of superficial infection (CD-I) treated by repeated dressings and oral antibiotics. However, significant complications were witnessed in the endovascular group only. Two patients (2/54;4%) had type-I endo-leaks after covered stent insertion. One case was managed conservatively (CD-II), and the other one needed another covered stent insertion (CD-III).

Mortality was seen in 4 patients (5%). All were in the operative group. Two patients presented in unstable condition from active bleeding. Ligation of the bleeding subclavian artery was needed in one case with zone-I injury. While ligation of carotid artery was done in the other case after zone-II injury. Regarding the other two mortalities; one was related to myocardial infarction 2 days post-surgical exploration. The other patient died from associated head injury after combined surgical intervention.

## DISCUSSION

The management of PNIs displayed pragmatic changes over last decade. Published data from high volume centres over last years inspired fundamental changes in management protocols towards more selective approaches.<sup>2,4-7,13</sup>

Since the early description of zone classification mandatory exploration (especially for zone-II injuries) was the mainstay of most treatment protocols for many decades.<sup>14,17-20</sup> However, this policy was challenged in the recent publications particularly after the development of 'no-zone approach' in 2013 by Shiroff et al.<sup>4,13,21,22</sup> This witnessed change was raised by the high rate of unnecessary surgical explorations 30-40%, the higher rate of complications and the increased hospital stay.<sup>13,23</sup>

Furthermore, the classification of neck zones only describes the entry wound of the causative injury with no description of the trajectory of the injury. Yet, a poor correlation sometimes exists between the location of the external wound and the injury of the internal structure.<sup>24-26</sup> In our study, we experienced two cases with slanting stab injuries causing internal injuries in different zones unrelated to the entry wound.

In addition, our analysis revealed no statistically significant correlation between the incidence of injuries and the injured zone (p value 0.9). This finding is consistent with many authors who declared that injured

zone shouldn't be a determinant in the management protocol of PNIs.<sup>4,6,13,26,27</sup>

Therefore, in this study we adopted a tailored selective protocol based on the use of physical examination and MDCT-A, with less dependence on zone classification, to decide the need of surgical intervention in the management PNIs.

By deploying this protocol, we reduced the negative explorations from 30-40% observed in the studies that used mandatory protocols to 7.4% (4/54 cases) only. This was comparable to most studies which applied similar selective protocols with 0-7% negative exploration rate.<sup>4,26,27</sup>

Within our follow up period, there were no missed major injuries or mortalities in the patients who had conservative management. The two missed nerve injuries (3.7%) were discovered post-surgery after repair of vascular injuries. Furthermore, the four (5%) encountered mortalities were in the intervention group, with only 2 direct neck injury-related death. Therefore, this low failure rate is comparable to most studies of selective approach with a rate of 0-3%.<sup>16,22,27</sup>

It's noteworthy to mention that we avoided 37% (31/85) non-therapeutic neck exploration with this protocol. This is consistent with other studies which selectively managed the patients, they avoided 30-80% unnecessary surgical explorations.<sup>18,22,26,27</sup>

The presentation with instability criteria, regardless the affected zone, indicated positive injuries in all patients with both specificity and positive predictive value of 100%. Thus, it's intuitive to advise an immediate exploration for all unstable patients. The presence of hard signs revealed positive injuries in 94% (17/18) of patients. Only one patient in this group, presented with expanding hematoma, was negative on exploration. Thus, the specificity and positive predictive value of hard signs were 97.1 and 94.4% respectively. This justifies our prompt intervention in all patients with hard signs, but it's certainly helpful to consider a pre-operative use of MDCT-A in zones I and III injuries to determine the possibility of endovascular intervention. It becomes clear that most protocols in PNIs recommended immediate surgical intervention in unstable patients and patients presenting with hard signs.<sup>7,15,21,22</sup>



The overall specificity and positive predictive value of soft signs were 75 and 45% respectively. This supports our more selective approach and the more exhaustive use of investigations in this category of patients. Only 10 (45%) of 22 patients with soft signs exhibited positive injuries. Likewise, in their large retrospective observational study, Isaza-Restrepo et al showed 38 (29%) injuries in 132 cases presenting with soft signs on arrival.<sup>21</sup>

It was noticeable that patients with history of bleeding witnessed by paramedics, had high specificity and positive predictive value of injury (97% and 75% respectively). Other soft signs, when presented alone, in form of stable hematoma (non-expanding and non-pulsating) or surgical emphysema were of less specificity and positive predictive value (83, 36, 90 and 20% respectively).

The absence of symptoms at presentation showed a high specificity of 92% in our study, which is comparable to most recent studies with a range of specificity from 90-100%.<sup>13,21,26</sup> This inspired many authors not to perform further investigations for asymptomatic cases at presentation.<sup>6,13,21,26,27</sup>

However, one of our asymptomatic patients (1/23;4%) turned out to be positive after MDCT-A, with a partial tear in CCA which was repaired by a saphenous venous graft on exploration.

While many recent studies emphasized that management of PNIs shouldn't be determined by the mechanism of injury.<sup>6,13,27,28</sup> Some advocate that transcervical bullet injury should be considered as a strong indicator for surgical exploration.<sup>29,30</sup> In this study, bullet injuries and road traffic accidents exhibited significant higher incidence of injuries (p value<0.001). However, we didn't include the mechanism of injury as a criterion for exploration in our protocol.

Given the current rise of MDCT-A use in PNIs, it's genuine that most high-volume trauma centres recommend its routine use in their recent management protocols.<sup>7,8,13</sup>

In our study, MDCT-A carried specificity of 97%, sensitivity of 77%, positive predictive value of 93% and negative predictive value of 89% in detection of injuries. These results are comparable to many published studies.<sup>5,10,13,26,31</sup> We experienced four false negative cases (4/53;7%) who required intervention despite unremarkable findings in MDCT-A scan. They were admitted initially with vascular soft signs which deteriorated clinically within few hours after admission that led to urgent exploration. This supports our mandatory observation of all patients for at least 48 hours before discharge.

This agreed high accuracy eliminated the traditional high demand for additional studies to assess the injuries. Thus, the routine use of such investigations in PNIs was put into question over last years.<sup>7,13,25,26</sup> Moreover, MDCT-A helps to predict the wound trajectory and determine any accompanied extra-cervical injuries as thoracic injuries.

While many authors advocated the routine use of duplex in neck injuries, we recommend its use as a complementary tool in some cases of zone II injuries.<sup>22</sup> Its use is markedly diminished after routine use of MDCT-A, though it held 95% specificity and 83% positive predictive value in our study. This is consistent with most studies.<sup>16,18,22</sup> Furthermore, the use of MDCT-A led to obvious decrease of the need for conventional angiography. Albeit, we support its use in zones I and III injuries when endovascular treatment is planned. In this current study, three out of six patients who underwent angiography, were managed by endovascular techniques.

It's worthy of mentioning that the sensitivity of MDCT-A in detecting the aero-digestive injuries is still limited compared to vascular injuries. It dropped to 53% in some reports.<sup>8,23,32</sup> Thereby, additional studies as contrast swallow or endoscopy should be potentially required in suspicious cases.

Our protocol didn't entail routine additional investigations for aero-digestive injuries. Our rationale was that aero-digestive injuries are commonly present with obvious clinical signs or with suspicious criteria at MDCT-A and hence they should be selectively investigated accordingly.<sup>13</sup> In addition, the reported incidence of such injuries in PNIs was low (0.9-8%).<sup>13,26,27</sup>

We didn't experience any missed aero-digestive injuries, despite the small number of these injuries in this study (13%). All aero-digestive injuries were detected either during exploration for unstable patients or presented with hard signs. However, 2 stable patients didn't present with hard signs and injuries were detected by extraluminal air in MDCT. Injuries were confirmed by bronchoscope and repair was done early.

This study should be interpreted in light of its inherited limitations; first, the number of involved patients was relatively small. Second, there were no determinate criteria in our protocol to use the additional investigations with MDCT-A.

However, there are some strengths to be emphasized; it's one of the fewest studies to apply a protocol in management of PNIs on a prospective basis. This ensured the uniformity of management that lacks in most retrospective studies published for PNIs. In addition, we managed to address the role of MDCT-A by its use as a mainstay in the management of PNIs.

## CONCLUSION

Our study provides a stimulus to use this selective protocol which is based mainly on MDCT-A and comprehensive physical examination in the management of PNIs. We recommend to reduce the reliance on zone classification in the future management protocols of PNIs. This selective tailored approach can considerably reduce the number of missed injuries and unnecessary explorations with no significant complications or mortalities.

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