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Subaxial cervical trauma surgical approach and neurological outcome

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Abstract
Objective: Subaxial cervical injury regards one of ten patients with spine trauma. The management of the injuries is either conservative or surgical. In this analysis we are dealing with the surgical approach and the postoperative neurological outcome.
Methods: We performed a retrospective analysis of the literature between 1997 and 2018. The included articles were analyzed with statistical program.
Results: The results suggest that the three available approaches are unequal regarding the neurological recovery, while the recovery itself depends also on the age group of the participants – a fact, suggesting the need of reevaluation of the therapy and its possibilities.
Conclusion: Subaxial cervical spine trauma is a complex issue with a new insight of management, which should be considered in the future.

Keywords: CSI, spine trauma, surgery, age, recovery

Introduction
The spine trauma in general could be a cause of permanent deterioration, impairment and economic burden. Cervical spine is the most common trauma region of the spine, while cervical spine injuries (CSIs) are accounting for about 3, 7% of all the traumatic injuries [1].
The onset of the symptomatology could be acute or delayed with different levels of neurological responses. In this regard, the American Spinal Injury Association (ASIA) has created a score system, similar to the Frankel scale, for the evaluation of the neurological status of the patients with spinal injuries [2]. It has the aim of establishment the need of further examination and guidance to the proper therapeutical approach.
The treatment options of the CSIs are conservative and surgical methods. Surgical management could be achieved via anterior, posterior or anterior-posterior approach. The final clinical result, however, depends on many other factors. Age is one of them and represents the subject of this analysis.

Methods
According to ASIA/ Frankel score system, there are a few kinds of spine trauma. The most serious is the complete injury or A score with no motor or sensory function. B, C and D scores are incomplete injuries, with the important clarification that B score has no motor function. (Figure 1) And finally, E score represents normal function [2, 3]. The validation and the determination of the prognostic value of these score systems are evaluated a hundred times. In this study, we aim to perform an analysis of the neurological outcome before and after surgery and to compare the neurological outcome of the possible surgical approaches. Furthermore, we aim to correlate the neurological outcome of the concrete approach with the age of the participants.
Because of the aforementioned, we collected the published data on Medline between 1997-2018 with MeSH terms: Spinal cord, Spinal cord injuries, Cervical cord, Spine surgery, Joint dislocation, Trauma, Spinal fractures/surgery and Fracture Dislocation/surgery.
Inclusion criteria are: Human studies; articles in English, Russian or German; articles reporting cervical subaxial facet fracture/dislocations; articles reporting the surgical approach; articles reporting demographic data; clinical studies based on ASIA or Frankel score system; articles reporting the pre- and postoperative ASIA/Frankel score or neurological status; case reports reporting neurological outcome; clinical studies; case series; and finally articles after 1997 year. (Figure 2. Flow chart).

On the other hand, exclusion criteria are: animal studies; articles written in other language than the above mentioned; articles with no demographic data; articles reporting conservative approach; articles reporting occipitocervical dislocations, C1 and C2 dislocations/fractures; reviews; comments; clinical studies that do not report ASIA score; letters to editor; and articles older than 1997 year.

The included studies were further analyzed with JASP 0.8.5.1. Statistical program.

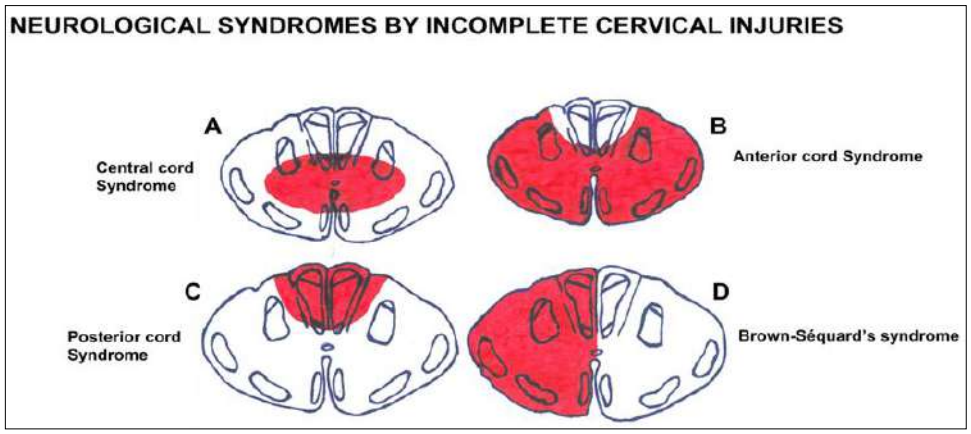

Fig 1: Cervical spine injury – neurological syndromes.

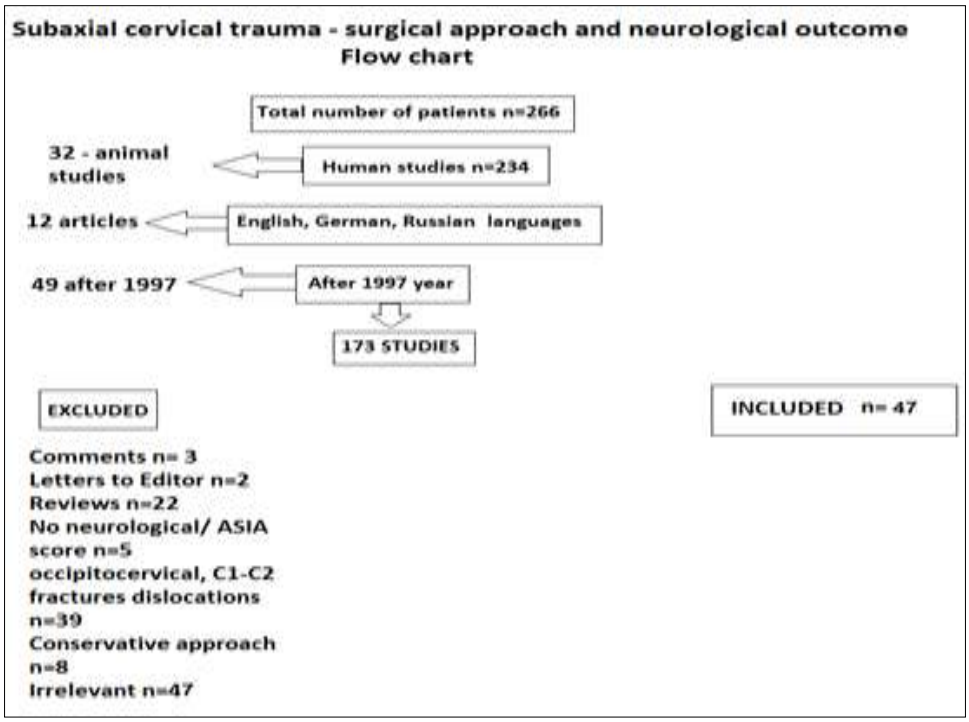

Fig 2: Flow chart.

Results

After processing the data, we included 47 studies with total number of 780 patients. (Table 1a, b and c) Mean age of the patients is 40,08. The most common cause of the CSIs are transport accidents, falls and blunt force trauma, resulting in cervical damage by distractive flexion (Figure 3). The therapy was administered in all of the cases after the first 8 hours.

Table 1a: List of included studies – Pediatric category

Study	Age	Improvement rate (%)	Approach
Chen *et al.* [4]	1,8	100	posterior
Li *et al.* [5]	3	100	anterior+posterior
Anissipour *et al.* [6]	14,9	36,36	anterior+posterior
Sellin *et al.* [7]	12,4	96,88	anterior+posterior
Momaya *et al.* [8]	10	100	posterior
Qu *et al.* [9]	5	100	anterior
Dogan *et al.* [10]	12,4	72,55	anterior
Shaked *et al.* [11]	9,5	100	anterior
Hooley *et al.* [12]	3	100	posterior

Table 1b: List of included studies – Geriatric category

Study	Age	Improvement rate (%)	Approach
Debija *et al*. [13]	67	75	anterior
Yokoyama *et al*. [14]	79	100	posterior
Yamazaki *et al*. [15]	62	100	posterior
Bartels *et al*. [16]	71,33	91,67	anterior+posterior
Moon *et al*. [17]	62	100	anterior
Raizman *et al*. [18]	55	100	anterior
Yang *et al*. [19]	55,42	75	anterior+posterior
Han *et al*. [20]	78	100	anterior+posterior
Abumi *et al*. [21]	56	54,35	posterior

Table 1c: List of included studies- Adult category

Study	Age	Improvement rate (%)	Approach
Wang *et al*. [22]	44,75	75	anterior+posterior
Du *et al*. [23]	40,1	100	anterior
Miao *et al*. [24]	41,3	80	anterior
Zhou *et al*. [25]	25	100	anterior
	30	100	posterior
Zhang *et al*. [26]	48	58,33	anterior
Park *et al*. [27]	45,5	76,19	posterior
Bunmaprasert *et al*. [28]	44	100	anterior+posterior
Prabhat *et al*. [29]	33	78,33	anterior+posterior
Ye *et al*. [30]	40,23	63,88	posterior
Jiang *et al*. [31]	46,9	78,57	anterior+posterior
Srivaswtava *et al*. [32]	42	100	anterior+posterior
Broughli *et al*. [33]	52	100	anterior
Ding *et al*. [34]	45,2	76,47	anterior+posterior
Zhang *et al*. [35]	47	62,5	anterior+posterior
Jiang *et al*. [36]	44,7	100	anterior+posterior
Nagata *et al*. [37]	54	26,67	posterior
Li *et al*. [38]	40,1	88,37	anterior
Schmidt- Rohlfing *et al*. [39]	36	100	anterior+posterior
Payer *et al*. [40]	51	100	anterior+posterior
Mizuno *et al*. [41]	50,4	20	anterior
	33	66,67	anterior+posterior
	45,33	66,67	posterior
Harrington *et al*. [42]	46	81,82	anterior
Choi *et al*. [43]	25	100	posterior
Razack *et al*. [44]	47	68,18	anterior
Kalayci *et al*. [45]	34	100	anterior
Lee *et al*. [46]	44,64	100	anterior
Feng *et al*. [47]	36,3	80,95	anterior+posterior
Basu *et al*. [48]	39	100	anterior+posterior
Jiang *et al*. [49]	41	60,52	anterior
Llαcer-Ortega *et al*. [50]	41,62	85,71	anterior+posterior

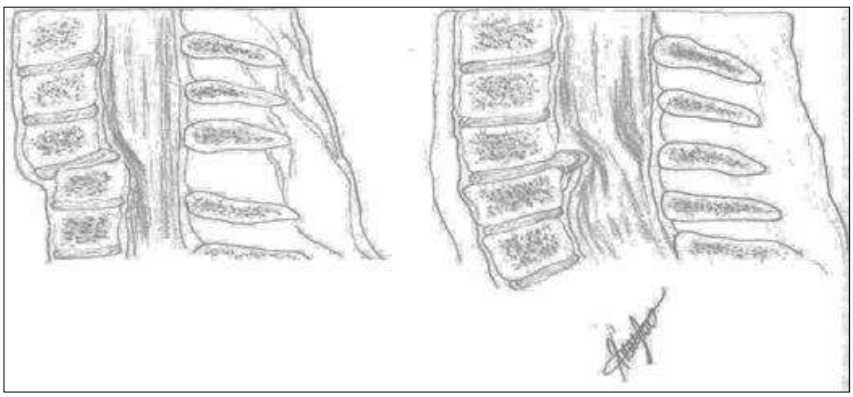

Fig 3: Cervical distractive flexion and compression before and after management.

For further analysis the patients were divided based on the mean age reported in the articles in three categories: Children (0-18 years), adults (18, 1-54, 9) and elderly (55 →). These patients were further divided based on the approach they had – anterior, posterior or combined (anterior+posterior).

On the other hand, the improvement/ recovery rate is established based in the ASIA score/ neurological clinical status, reported in the studies. Every enhancement of the ASIA score or the neurological status is considered improvement, regardless the initial score, while no change in A or B score or neurological status is considered as no improvement. Every improvement is evaluated with 100%, while no improvement – 0%. The average score of the study represents the sum of recovery rates of all patients, divided by the number of patients:

$$\text{Recovery Rate/ Improving Rate} = \frac{\text{SUM OF THE RECOVERY RATES}}{\text{NUMBER OF PATIENTS}}$$

Paired T-test was run for the three approaches, creating a few combinations. The first combination is children versus adults; the second combination is adults versus elderly and the third - children versus elderly. The null hypothesis of the test is M1≠ M2, meaning that p-values over 0,5/0,01/0,001 confirm the hypothesis (the both sites are unequal), while p-values under the latter – reject the hypothesis (equal sites).

The outcome of the test reveals significant results. (Table 2a-c) First of all, all of the T-paired tests for the combined approach show that the improvement rate of the patients, as well as the age between the categories is unequal. (Table 2a) Furthermore, analyzing the R^2 factor in the regression analysis, we found that the correlation between age and improvement is strongly positive in elderly (R2 = 0,9983), neutral in adults (R2=0,0155) and moderate negative in children (R2=-0,4823).

Table 2a: Paired T-test for the combined approach for the three subcategories – elderly, adults and children.

	Adults vs. Elderly		Elderly vs. Children		Children vs. Elderly	
	Age	**Improvement**	**Age**	**Improvement**	**Age**	**Improvement**
p-value	0.044*	0.897	0.022*	0.513	0.026*	0.771
Df	2	2	2	2	2	2
T	-2.264	-0.147	-6.571	-0.788	-9.851	-0.333

*Significance of the p-value 0.05

The second run of the paired T-test concern the posterior only approach. The neurological recovery rate was unequal in all of the three combinations, while the age showed inequality only for the elderly versus children group and equality for the other two. (Table 2b) Regarding the correlation analysis for the posterior only approach, there is a moderate positive correlation (R2=0,4924) between age and improvement in the elderly group; slightly positive in the children group (R2=0,1429) and strongly negative in the group of the adults (R2=-0,8317).

Table 2b: Paired T-test for the posterior only approach for the three subcategories – elderly, adults and children.

	Children vs. elderly		Elderly vs. adults		Adults vs. Children	
	age	**improvement**	**age**	**improvement**	**age**	**improvement**
p-value	0.006**	0.423	0.103	0.874	0.075	0.635
Df	2	2	2	2	2	2
T	-13.127	-1.000	-2.036	-0.179	-3.582	-0.555

**Significance of the p-value 0.01

Finally, the paired T-test for the anterior only approach showed inequality of the improvement and equality of the age among the latter categories. (Table 2c) The correlation analysis showed that the relation between age and recovery is neutral in the adult group (R2=0,0505), and strongly negative in the pediatric group (R2=-0,6359) and in the geriatric group (R2=-0,6628).

Table 2c: Paired T-test for the anterior only approach for the three subcategories – elderly, adults and children.

	Elderly vs. children		Children vs. adults		Elderly vs. Adults	
	age	**improvement**	**age**	**improvement**	**age**	**improvement**
P	0.009	0.962	0.044*	0.423	0.011**	0.910
Df	2	2	2	2	2	2
T	-10.558	-0.054	4.582	1.000	-9.461	0.128

*Significance of the p-value: 0,5, **More significant p-value: 0,01

These findings suggest that the approach should be considered before further proceeding, based on the age of the patients. For elderly patients, the combined approach seems to be more proper for the achievement of better recovery, followed by the posterior only approach. The anterior only approach in this category is negatively correlated with the improvement rate, meaning that the "younger" mature would benefit more.

On the other hand, the posterior only approach seems to be more eligible for the children. The rest (combined and anterior only approach) are negatively related to the neurological recovery rate, suggesting that they are suitable for younger children.

And finally, in adults the combined approach has no impact on the final outcome, while the other two have negative relations, suggesting that the younger adults would benefit more from the posterior, while these in the middle–from the anterior. (Figure 4)

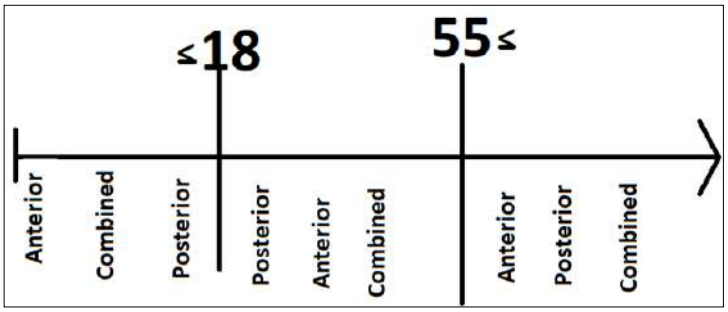

Fig 4

Discussion

Subaxial facet fractures and dislocations account for about 10% of the CSIs [51]. Normally their mechanism of injury is the distractive – flexion, one of the six mechanisms of spine injury [52]. The classification of Allen, however, is replaced by newer, more detailed model that provides better understanding of the spine trauma and guidance to the proper therapeutical method [53]. The management of the spinal trauma is done by a conservative approach or with closed reduction or internal fixation by anterior, posterior or combined (anterior+posterior) surgical approaches. The common aim is to achieve spinal cords decompression, stabilization and pain relief [54].

The anterior approach is believed to be much easier in the positioning of the patients, for the access of the spine and for the visualization of the problem [54]. This approach, however, has the disadvantage regarding the instrumentation placing and complication such as instrumentation failure, nerve palsy, artery occlusion, fistula, infection, hemorrhage and thrombotic episodes [54, 26, 13]. The approach is seldom used in children because of the hazard of postoperative instability and distortion [9]. Despite that fact, the neurological outcome of this age group seems to be outstanding. Regarding the other two age groups, the anterior facetectomy appears to be a good choice, which, as suggested, should be performed by very qualified teams because of the complication risks, related to the approach [26, 13]. According to our analysis, this approach has its considerations, calculating the outcomes in every age group.

On the other hand, posterior only approach was the most common used approach in the past. It has the benefit of good visualization, stability and good instrumentation positioning [25, 54]. Despite the fact that the method is linked to more invasiveness, the rates of complications are low, while the neurological outcome is very promising [54, 25, 41].

Finally, the combined approach bares the risk of complications of the both methods [54]. Regarding the neurological outcome and the fusion rates, neither Harrington and his colleagues [42], nor Lee *et al*. [55] found any difference in the results. On the other hand, we found a significant difference in the neurological outcome based on approach and age. For certain, the three approaches are unequal. According to the analysis, however, the final neurological improvement is linked to the age group, which has never been shown until now.

Finally, the neurological recovery after spine trauma, according to Jug *et al*. [56] is linked to the hour of surgical intervention. His study suggests that the neurological recovery has odds ratio of 106% for improvement in those who had intervention in the first 8 hours. The model of early surgery, however, is very unlikely for the majority of the cases. Jain and his colleagues [57] report a study if delayed surgery for subaxial cervical trauma, where the neurological recovery of the patients were intact. All of the studies in this analysis report an intervention after the 8 first hours and according to it, other factors playa major role to the final outcome. In an agreement of the report of Jug *et al*. [56] the odds ratio of neurological recovery are equal between the patients with incomplete injury (B,C,D ASIA/Frankel grades) and complete spine injury (A grade), supporting the final results of our study that the neurological improvement does not depend on the preoperative scores and the intervention's hour, but on the age and type of surgical intervention.

Cervical spine injury could lead to permanent deterioration, mutilation and economic burden [58]. The hospitalization of the injured patients is estimated at 2,67 billion Dollars yearly in Canada. A fact, raising the question, whether it is being administered unnecessary treatment or the CSIs lead to permanent need of health care. In this term, the current analysis shows that based on the age, there are a few thoughts regarding the surgical approach that could be taken under consideration in the future. Age is a significant factor to the final neurological outcome. And as this study shows, the age plays also a significant role to the surgical approach, raising the concern whether we should reevaluate the surgical approach of the subaxial CSIs and make it more suitable to the age category of the patients.

The authors have no conflict of interests to declare

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