COMBAT RELATED SPINE AND SPINAL CORD INJURIES: A SYSTEMATIC LITERATURE REVIEW AND META-ANALYSIS

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Objective. To study the epidemiology and clinical features of spinal injuries and wounds in combat situations.
Material and Methods. A systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using PubMed and Cochrane Library databases. Statistical analysis of the data was performed using the R statistical programming language in the RStudio integrated development environment. The *meta* and *metafor* libraries were used for meta-analysis. The Knapp-Hartung correction was used to calculate the confidence intervals of the pooled effects.
Results. Of the 30 full-text articles, 11 met the required criteria and were included in this review with STROBE assessment. The mean age of the injured was 26.58 years (95% CI: 25.8–27.4 years; $I^2 = 0\%$; $p = 0.65$), males accounted for 98% (95% CI: 98–99; $I^2 = 37\%$; $p = 0.1$), closed spinal cord injury was diagnosed in 47.11% of cases (95% CI: 28.83–66.19%; $I^2 = 99\%$; $p < 0,01$), and gunshot wounds – in 43.64% (95% CI: 23.94–65.59%; $I^2 = 99\%$; $p < 0.01$). Cervical injures were recorded in 32.13% of cases (95% CI: 17.75–50.94%; $I^2 = 95.1\ \%$; $p < 0.01$), thoracic injuries – in 34.28% (95% CI: 22.58–48.27%; $I^2 = 88\%$; $p < 0.01$), lumbar injuries – in 57.16% (95% CI: 44.52–68.92%; $I^2 = 97.5\%$; $p < 0.01$), and sacral – in 21.23% of cases (95% CI: 16.99–26.21%; $I^2 = 76\%$; $p < 0.01$).
Conclusion. The results emphasize the peculiarities of the modern epidemiology of combat related spine and spinal cord injuries and wounds. Conflicts of the 21st century are characterized by the predominance of mine and explosive action; as a rule, young people suffer, the overwhelming majority of them are men; at least 30% of wounded with gunshot injuries to the spine require surgical treatment. The vast majority of authors choose isolated posterior fixation. The most common complications include thromboembolic complications, urinary tract infections, pneumonia and bedsores.
Key words: combat spinal injuries; spine and spinal cord injury; gunshot wounds of the spine; meta-analysis of the spine and spinal cord injuries.
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Spinal wounds are characterized with high mortality, severe permanent disability, and many complications [1]. During the 20th and 21st centuries, the percent of spineand spinal cord injuries ranges from 1.2% in the Korean War 1950–1953 to 7.4% of all losses during the US military campaign in Iraq [2, 3]. During the Great Patriotic War, spinal wounds amounted 0.3% to 1.5% on different fronts [4]. The widespread use of high-power firearms has changed the nature of wounds: shrapnel wounds have become more common than bullet ones in the profile of gunshot injuries [5]; while an increase in the percent of spinal pathology in the overall profile of injuries and wounds was observed, as well as the improvement in the evacuation arrangement and diagnostic procedures. Spinal wounds received in areas of military conflicts differ from injuries in peacetime, primarily, because of the high percent of combined injuries [6, 7].

The objective was to analyze the epidemiology and clinical features of spinal injuries and wounds in combat situations, as well as to summarize the analyzed parameters using a systematic literature review and meta-analysis.

Material and Methods

Article selection

Systematic literature review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. The main search was performed using the PubMed (Medline section) and Cochrane Library databases. Queries included the following keywords: stabilization AND combat AND spine trauma; combat-related AND spinal fracture; unstable AND combat AND spinal fracture; ((Schoenfeld[Author]) AND (spine))

AND (trauma)); ((“spinal fracture”) OR (“spinal injury”)) AND ((“military”) OR (“combatants”)) AND ((“treatment”) OR (“stabilization”) OR (“fixation”)); (“Combatant” OR “Military”) AND (“spine injury” OR “spine fracture”); combat spine injury. The search period was 2000 to September 2024, and human subjects researches were exclusively selected (Fig. 1).

Abstracts and full texts of the articles were initially reviewed. The systematic review included original articles describing the epidemiology and demography of combat-related spinal injuries. Articles of the following types were not included in this research: clinical case, experimental research, abstracts of conference reports, and systematic review. Table 1 provides the criteria for inclusion and non-inclusion of articles in the research.

Data collection

Information from each article was entered into a Microsoft Excel table. If the corresponding information was missing in the text of the article, the cells were filled with “NA” (not available). Basic information included the authors’ last names and initials, year and design of the study, assessment of the article compliance with the STROBE guidelines (described below), number of subjects, mean age, sex, type of injury (closed trauma/gunshot wound), distribution by spinal department, initial neurological deficit according to the American Spinal Injury Association (ASIA) Impairment Scale (AIS), information on the neurosurgical procedures performed (posterior, anterior, circular fusion; dura mater sealing; spinal canal decompression), changes in neurological deficit over time, and complications. All selected articles were assessed for compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [9]. Compliance with the STROBE checklist items was assessed as 0 points (if not met) or 1 point (if the recommendation were met). If an item includes several sub-items (i.e. items 1, 6, 12, 13, 14, and 16), 1 point was assigned provided that most of the sub-items were met. A maximum of 22 points for this checklist would indicate that the article met the requirements for publications of high methodological quality.

Statistical analysis

Statistical analysis of the data was performed using R language and environment (version 3.6.1) in RStudio IDE (version 1.3.1093). Since we expected significant methodological and statistical heterogeneity in the studies reviewed, a mixed effects model was used to calculate the effect size. The restricted maximum likelihood estimation was used to calculate the variance of heterogeneity 2 [10]. The Hartung-Knapp correction was used to calculate the confidence interval of the pooled effect [11]. Heterogeneity was assessed using the I^2 test. Heterogeneity was considered low with I^2 <50%, moderate with I2 from 50 to 75%, and high with I^2 >75% [12].

Results

Article selection

The initial search in PubMed and Cochrane Library databases revealed 302 articles as the search result. After applying filters and removing duplicates, 30 works were selected to review the full-text versions; 11 of them met the specified criteria and were included in this review and assessed for compliance with STROBE (Table 2).

General features of patients

A meta-analysis of the mean age, sex profile, and nature of wounds was performed. The mean age was 26.58 years (95% CI: 25.8–27.4 years; I^2 = 0%; p = 0.65), with 98% of male patients (95% CI: 98–99; I^2 = 37%; p = 0.1); closed spinal trauma was diagnosed in 47.11% of cases (95% CI: 28.83–66.19%; I^2 = 99%; p < 0.01), gunshot wounds – in 43.64% (95% CI: 23.94–65.59%; I^2 = 99%; p < 0.01), mine-blast wounds were observed in 51.82% of patients (95% CI: 29.94–73.02%; I^2 = 98%; p < 0.01); bullet wounds – in 14.88% (95% CI: 13.31–16.61%; I^2 = 12%; p = 0.34). The results are provided as forest-plots (Figs. 2–7). Detailed description of the populations for each article is given in Tables 3 and 4. Heterogeneity turned out to be low for the statistics of bullet wounds; according to most authors, it indicates a low percentage of bullet wounds in the overall profile of injuries.

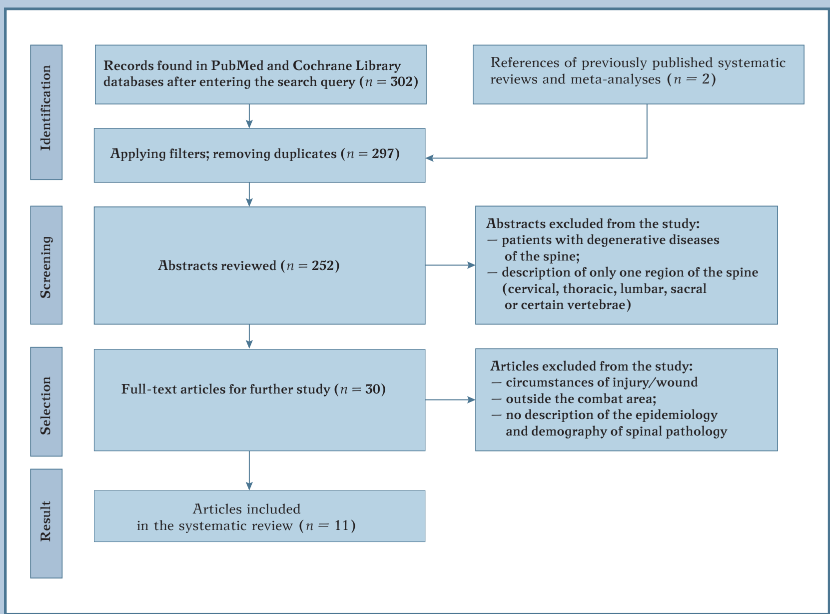

Fig. 1
Algorithm for searching and selecting articles in accordance with PRISMA guidelines

Injuries to the cervical spine were registered on mean in 32.13% of cases (95% CI: 17.75–50.94%; I^2 = 95.1%; $p < 0.01$), to the thoracic spine – in 34.28% (95% CI: 22.58-48.27%; I^2 = 88%; $p < 0.01$), to the lumbar spine – in 57.16% (95% CI: 44.52–68.92%; I^2 = 97.5%; $p < 0.01$), and to the sacrum – in 21.23% (95% CI: 16.99–26.21%; I^2 = 76%; $p < 0.01$). The results are provided as forest-plot (Fig. 8); the detailed distribution for each article is shown in Table 5.

Combat-related injuries often have a combined nature [5]. A method for impartial assessing the severity of combined damage is calculating points according to the injury severity score (ISS) system [20]. Combat-related wounds are characterized by high ISS, 32.76 points on mean, which is considered a borderline injury [13, 15, 17, 19].

Features of neurological disorders in the wounded patients

Evaluation of spinal cord injuries was carried out according to the ASIA scale (AIS) [21]. The severity of spinal cord injury is characterized as follows: ASIA A means patients with complete motor and sensory impairments below the level of injury; ASIA B means patients with complete motor and incomplete sensory impairments; ASIA C indicates patients with incomplete motor deficit and more than half of the key muscle functions below the neurological level of injury having a muscle grade less than 3 points; ASIA D describes patients with incomplete motor deficit and more than the half of the key muscle functions below the neurological level of injury having a muscle grade more than or equal to 3 points; and ASIA E means no impairments. Tables 6 and 7 demonstrate that the proportion of patients with complete neurological deficit is quite high and ranges 6.67% to 40.00% of all injured patients. Such a wide range is related to the objectives and material of the studies. Thus, Blair et al. [18] and Possley et al. [1] used the Joint Theater Trauma Registry as a database; it includes information on all military personnel with combat-related injuries. Accordingly, the studies included patients with spinal cord injury as not the main condition. The results of the meta-analysis are provided in Fig. 9.

We should mention the poor prognosis for patients with severe neurological deficit (ASIA A and B) [13–15]: one patient demonstrated an improvement from ASIA A to B. However, the authors observed positive changes over time in four patients with milder neurological deficit (ASIA C and D).

Surgical treatment of patients with combat-related spinal injuries

In large cohort studies, neurosurgical treatment was provided to less than a third of all subjects (31.35%) [1, 7, 18]. Stabilization surgeries for spinal instability were performed in 78.55% of the wounded individuals who underwent surgery, and decompression of the spinal canal was required in 59.71% of cases (Table 8). No data on the use of minimally invasive techniques are provided.

Statistical data obtained in small studies with all patients received surgical treatment demonstrated that instability in a spinal motion segment was also the main reason for spinal surgery: in 80%–100% of all surgical interventions. Meta-analysis of surgeries is provided in Fig. 10 and 11. Decompression was performed in 15.00%–93.33% of cases (Table 9). On mean, patients underwent surgery on day 1.8 after injury or wound [13–15].

Table 1

Criteria for inclusion and non-inclusion of articles in the study

Inclusion criteria	Non-inclusion criteria
The subjects of the study are patients who have suffered a spinal injury or wound in combat situations.	The study subjects are patients who have suffered a spinal injury or wound outside a combat area.
The study describes the epidemiology of injuries to all spinal regions	The study subjects are patients with degenerative spinal diseases
Date of study: 2000 to September 2024	The study describes damage to only one spinal region (cervical, thoracic, lumbar, sacral, or certain vertebrae)
Availability of a full-text version of the article in English or Russian	

Table 2

Selected articles, study design presented in the article, STROBE assessment and evidence level of the article

Authors	Year	Study design	STROBE	Evidence level
Formby et al. [13]	2016	Retrospective cohort	13	III
Ravindra et al. [14]	2016	Retrospective cohort	11	III
Schoenfeld et al. [15]	2014	Retrospective “case – control”	17	III
Schoenfeld et al. [3]	2012	Retrospective cohort	13	III
Blair et al. [7]	2012	Retrospective cohort	15	III
Schoenfeld et al. [16]	2013	Retrospective cohort	18	III
Szuflita et al. [6]	2016	Retrospective cohort	18	III
Possley et al. [1]	2012	Retrospective cohort	16	III
Schoenfeld et al. [17]	2013	Retrospective cohort	18	III
Blair et al. [18]	2012	Retrospective cohort	13	III
Galvin et al. [19]	2014	Retrospective cohort	14	III

Complications

The most common complications were infectious ones: bedsores, pneumonia, and urinary tract infections (Table 10). Postoperative complications included screw malposition, incorrect screw position, insufficient spinal canal decompression, postoperative wound dehiscence, and postoperative liquorrhea (according to Possley et al. [1], the latter occurred in 4 cases out of 184 surgeries). Mortality was 2.55% (95% CI: 0.39–14.94%; $I^2 = 81.9\%$; $p < 0.01$; Fig. 12).

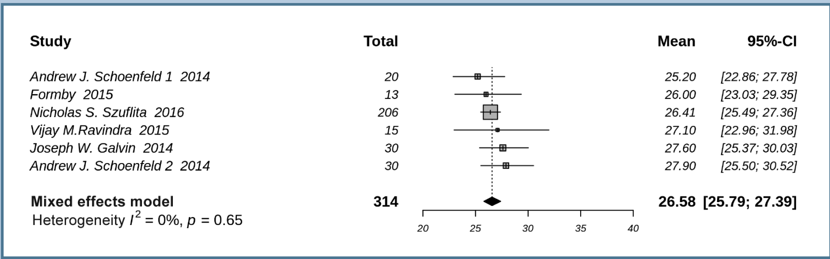

Fig. 2
Result of the meta-analysis of a mean age of patients: squares show the weighted effect size for each specific study (the size of the squares corresponds to the weight of the studies), black segments – the 95% confidence interval, the black diamond – a weighted mean value of a mean age; 95% CI – the confidence interval

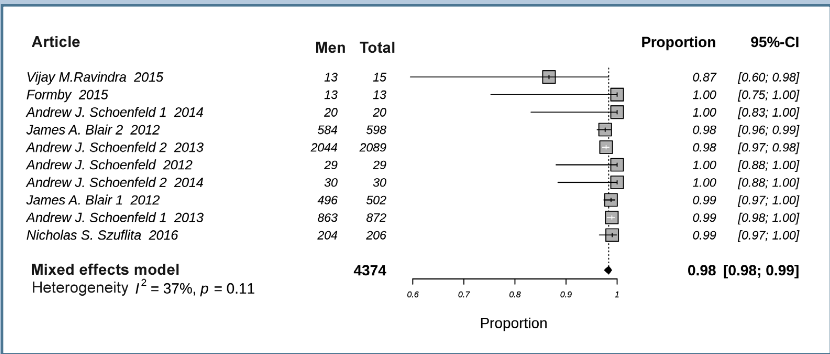

Fig. 3
Result of the meta-analysis of sex distribution (see the symbol legend to Fig. 2)

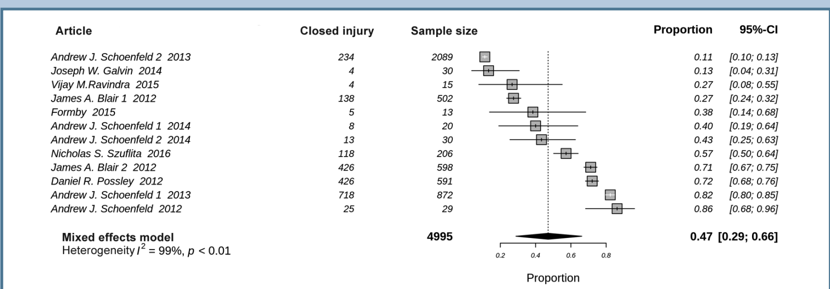

Fig. 4
Result of a meta-analysis of the incidence of closed spinal injury (see the symbol legend to Fig. 2)

Discussion

The end of the 20th and the beginning of the 21st centuries may be described in terms of a relatively small number of military conflicts with the participation of large countries: the only exceptions were the US military campaigns in the Middle East and Afghanistan. As a result, there were not much research publications on combat-related traumas. The most complete data were obtained for the above conflicts; however, we have found no meta-analyses concerning combat-related spinal injuries. There was one systematic review describing spinal injuries and wounds from the World War II to the US special campaign in Afghanistan [22], with the limitation represented by the different research target: several articles include patients with damage to only one spinal region or with one injury type. Another shortcoming is the inclusion of patients with non-combat-related spinal injuries. We excluded such articles from our analysis leaving only those that describe combat-related injuries.

If the original studies described spinal traumas in peacetime as well, we used only information that referred to combat-related injuries. We face with a challenge during our research: it was not possible to comprehensively systematize clinical information about patients in the selected studies (severity of neurological deficit, combined organ damage, foreign body removal, dura mater sealing, as well as clinical outcomes depending on the amount of treatment provided). Only Formby et al. [13] demonstrated particular complications and also mentioned that 5 out of 13 patients underwent dura mater sealing. A prospective trial is required that includes study of the epidemiology, clinical features, neurosurgeries, and patient treatment outcomes using conventional classifications and questionnaires.

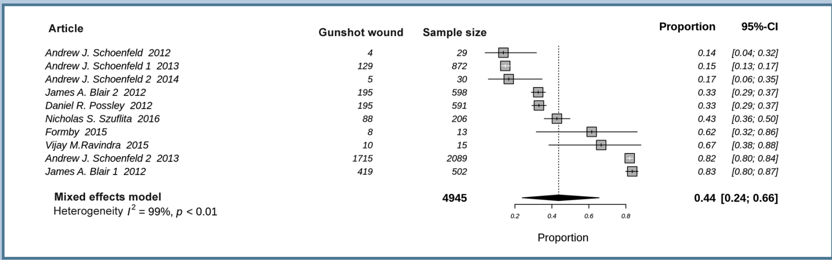

Fig. 5
Result of a meta-analysis of the incidence of spinal gunshot wounds (see the symbol legend to Fig. 2)

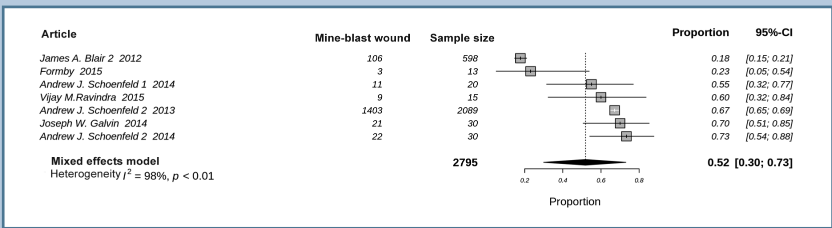

Fig. 6
Result of a meta-analysis of the incidence of spinal mine-blast wounds (see the symbol legend to Fig. 2)

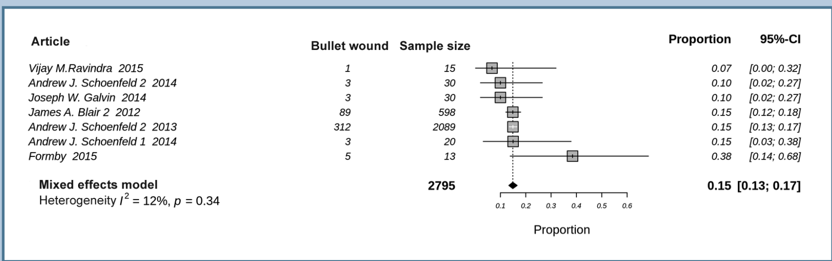

Fig. 7
Result of a meta-analysis of the incidence of bullet wounds (see the symbol legend to Fig. 2)

Limitations

There are limitations that should be considered when summarizing the results of the analyzed articles. First, cohort studies are subject to potential bias and also have differences in the data collection methodology, especially when assessing neurological deficits and surgeries performed; for large observational studies, large trauma registries were used as a source of data [1, 7, 16–18], therefore, patients with minor injuries were also included (this may be indicated by a large number of patients without neurological deficit). Second, the objectives of the original studies varied: from providing general epidemiological data to describing particular complications. This increases the heterogeneity of the selected articles (Figs. 4–6, 8) in the meta-analysis of the distribution of neurological deficits to ASIA A and E. Currently, there are no studies that fully describe the epidemiology, clinical presentation, treatment, and outcomes of this condition; there are only articles dealing with a narrow issue of combat-related spinal injuries. Most studies do not include the analysis of the relations between factors and their effect on the disease course and treatment outcomes; so, they are sketchy, and the surgeon cannot make a decision on treatment strategy. For example, there are no studies describing the effect of the timing and volume of surgical care on the regression of neurological deficit, the development of surgical complications, and patient's quality of life in the early and late periods of spinal trauma. To get an impartial description of combat-related injuries, we restricted our attention to the conflicts of the 21st century and

Table 3
Features of combined injuries

Author	Year	Patients, n	ISS	Combined injuries				
				Head and neck	Chest	Abdomen	Extremities	Pelvis
Formby et al. [13]	2016	13	22.7	NA	NA	NA	NA	NA
Schoenfeld et al. [15]	2014	20	21.5	NA	NA	NA	NA	NA
		30	36.1	NA	NA	NA	NA	NA
Schoenfeld et al. [16]	2013	2089	57.4	NA	NA	NA	NA	NA
Blair et al. [18]	2012	598	NA	1.466	924	1.365	1.323 + 1.141	985
Galvin et al. [19]	2014	30	26.1	136	159	149	NA	NA

Table 4
Demographic and epidemiological data of injured in combat area individuals with damage to the spine and spinal cord

Autho	Year	Patients, *n*	Mean age	Men		Closed injury		Gunshot wound		Mine-blast wound		Bullet wound		Other	
				%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Formby et al. [13]	2016	13	26	100.00	13	38.46	5	61.54	8	23.08	3	38.46	5	NA	NA
Ravindra et al. [14]	2016	15	27.1	86.67	13	26.67	4	66.67	10	60.00	9	6.67	1	6.67	1
Schoenfeld et al. [15]	2014	20	25.2	100.00	20	40.00	8	NA	NA	55.00	11	15.00	3	30.00	6
		30	27.9	100.00	30	43.33	13	16.67	5	73.33	22	10.00	3	16.67	5
Schoenfeld et al. [3]	2012	29	27.8	100.00	29	86.21	25	13.79	4	NA	NA	NA	NA	NA	NA
Blair et al. [7]	2012	502	26.3	98.80	496	27.49	138	83.47	419	NA	NA	NA	NA	NA	NA
Schoenfeld et al. [16]	2013	872	26.6	98.97	863	82.34	718	14.79	129	NA	NA	NA	NA	2.87	25
Szuflita et al. [6]	2016	206	26.41	99.03	204	57.28	118	42.72	88	NA	NA	NA	NA	4.37	9
Possley et al. [1]	2012	591	26	NA	NA	72.08	426	32.99	195	NA	NA	NA	NA	NA	NA
Schoenfeld et al. [17]	2013	2089	26.6	97.85	2044	11.20	234	82.10	1715	67.16	1403	14.94	312	6.70	140
Blair et al. [18]	2012	598	26.5	97.66	584	71.24	426	32.61	195	17.73	106	14.88	89	1.17	7
Galvin et al. [19]	2014	30	27.6	NA	NA	13.33	4	NA	NA	70.00	21	10.00	3	6.67	2
Mean value		–	26.67	97.90	–	47.47	–	44.73	–	52.33	–	15.71	–	7.51	–

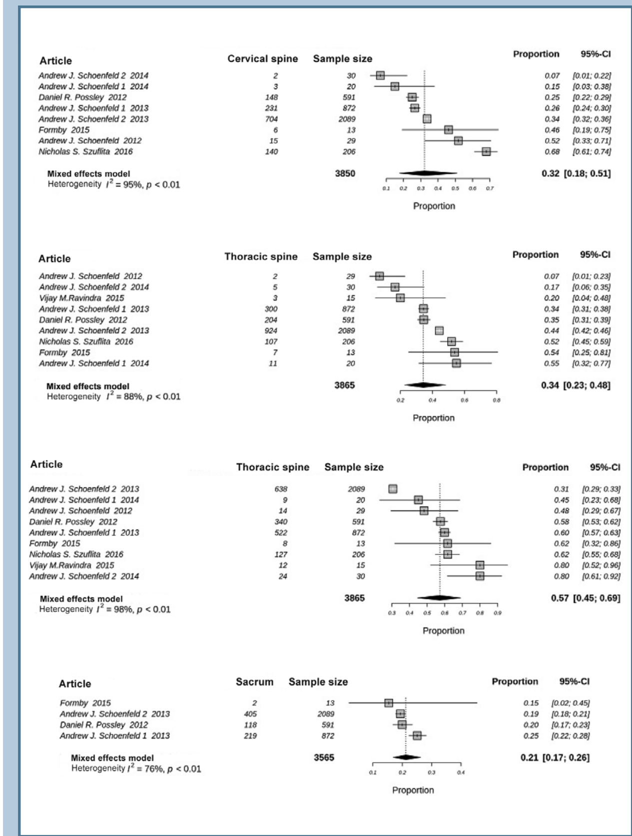

Fig. 8
Meta-analysis of the profile of spinal injuries by departments (see the symbol legend to Fig. 2)

excluded the works related to only one spinal region, only penetrating wounds, or only closed spinal injuries.

Conclusion

Data on the epidemiology, clinical presentation, and treatment outcomes in patients with gunshot wounds to the spine and spinal cord are very limited in the world literature because of different approaches to collecting and processing information.

Nevertheless, all researchers confirm that the overwhelming majority (98%) of individuals with combat-related injuries are young males, with a mean age of 26.58 years (95% CI: 25.8–27.4 years).

It seems to be impossible to exactly categorize the presenting patients based on the nature of their injuries (closed injury or gunshot wound) in the analyzed literature. The sample and conditions of patient enrollment are characterized with a very high heterogeneity.

At that, during the last decade, there has been a trend to the increasing percentage of gunshot shrapnel wounds resulting

Table 5

Distribution of spinal injuries by levels

Author	Year	Patients, n	Cervical spine		Thoracic spine		Lumbar spine		Sacrum		Number of damaged vertebrae per an individual
			%	*n*	%	*n*	%	*n*	%	*n*	
Formby et al. [13]	2016	13	46.15	6	53.85	7	61.54	8	15.38	2	3.2
Ravindra et al. [14]	2016	15	NA	NA	20.00	3	80.00	12	NA	NA	NA
Schoenfeld et al. [15]	2014	20	15.00	3	55.00	11	45.00	9	NA	NA	NA
		30	6.67	2	16.67	5	80.00	24	NA	NA	NA
Schoenfeld et al. [3]	2012	29	51.72	15	6.90	2	48.28	14	NA	NA	1.07
Blair et al. [7]	2012	502	14.29	262	27.86	511	41.33	758	41.83	210	3.7
Schoenfeld et al. [16]	2013	872	26.49	231	34.40	300	59.86	522	11.94	219	1.5
Szuflita et al. [6]	2016	206	67.96	140	51.94	107	61.65	127	NA	NA	NA
Possley et al. [1]	2012	591	25.04	148	34.52	204	57.53	340	19.97	118	NA
Schoenfeld et al. [17]	2013	2089	33.70	704	44.23	924	30.54	638	19.39	405	1.11
Blair et al. [18]	2012	598	15.18	319	28.13	591	40.79	857	10.95	230	NA
Galvin et al. [19]	2014	30	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean value		–	30.22	–	33.95	–	55.14	–	19.91	–	–

Table 6

Initial values of neurological deficit

Author	Year	Patients, *n*	ASIA A		ASIA B		ASIA C		ASIA D		ASIA E		Incomplete injury	
			%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Formby et al. [13]	2016	13	30.77	4	15.38	2	23.08	3	23.08	3	7.69	1	NA	NA
Ravindra et al. [14]	2016	15	40.00	6	13.33	2	6.67	1	13.33	2	26.67	4	NA	NA
Schoenfeld et al. [15]	2014	20	20.00	4	5.00	1	5.00	1	20.00	4	50.00	10	NA	NA
		30	6.67	2	13.33	4	23.33	7	36.67	11	20.00	6	NA	NA
Possley et al. [1]	2012	591	7.78	46	NA	NA	NA	NA	NA	NA	83.76	495	8.80	52
Schoenfeld et al. [17]	2013	2089	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Blair et al. [18]	2012	598	7.86	47	NA	NA	NA	NA	NA	NA	82.61	494	8.70	52
Galvin et al. [19]	2014	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 7

Final values of neurological deficit

Author	Year	Patients, *n*	ASIA A		ASIA B		ASIA C		ASIA D		ASIA E	
			%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Formby et al. [13]	2016	13	30.77	4	15.38	2	23.08	3	23.08	3	7.69	1
Ravindra et al. [14]	2016	15	40.00	6	13.33	2	0.00	0	20.00	3	26.67	4
Schoenfeld et al. [15]	2014	20	20.00	4	5.00	1	0.00	0	25.00	5	50.00	10
		30	3.33	1	16.67	5	16.67	5	36.67	11	23.33	7

from the explosion of artillery ammunition and explosive devices.

The neurological deficit associated with such wounds is persistent. According to most studies, the least favorable prognosis for the recovery of neurological functions or regression of neurological deficit is observed in patients with a complete functional disruption of the spinal cord.

According to cohort studies, at least 30% of individuals with spinal gunshot

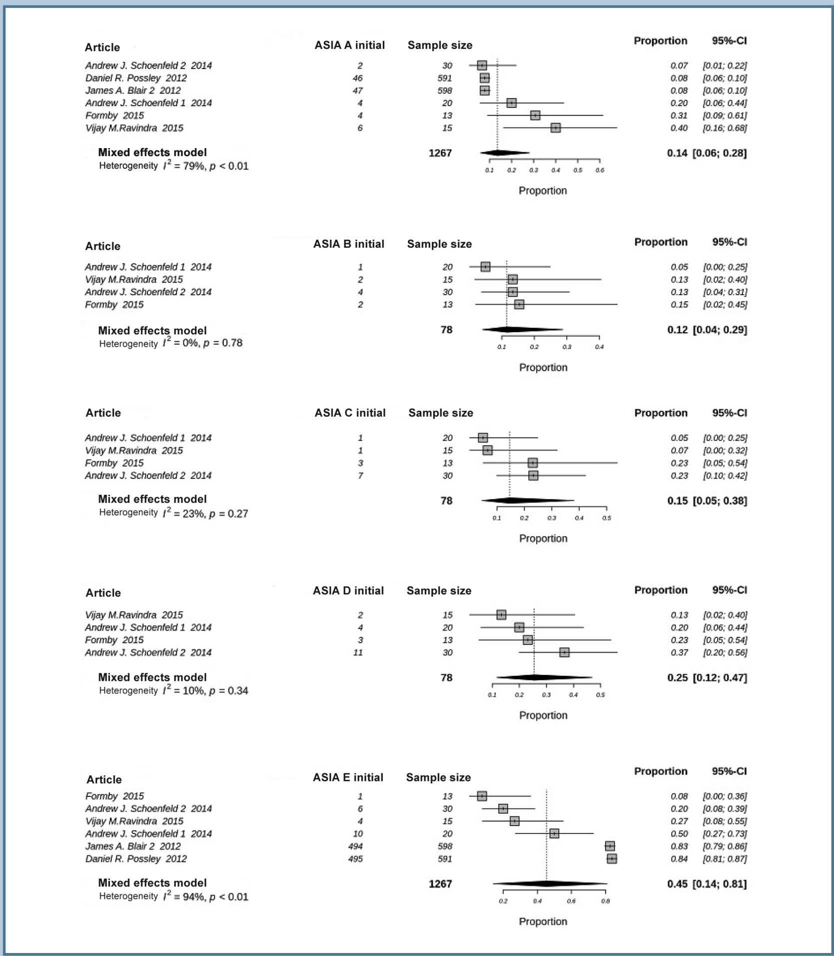

Fig. 9
Meta-analysis of neurological deficit in patients at the beginning of the study: complete neurological deficit (ASIA A) – 13.57% of cases (95% CI: 5.93–28.12%; $I^2 = 79.4\%$; $p < 0.01$), ASIA B –11.54% (95% CI: 4.05–28.72%; $I^2 = 0\%$; $p = 0.78$), ASIA C – 14.69% (95% CI: 4.61–38.04%; $I^2 = 23.3\%$; $p = 0.27$), ASIA D – 25.46% (95% CI: 11.7–46.83%; $I^2 = 9.7\%$; $p = 34$), without neurological deficit (ASIA E) – 45.49% (95% CI: 14.16–80.86%; $I^2 = 94.1\%$; $p < 0.01$)

injuries required surgical treatment. The need for spinal stabilization should be further analyzed, as it appears from many different approaches to treatment strategy. Nevertheless, the overall majority of authors (72%) selected isolated posterior fixation. Anterior fusion and circular fixation were performed in 8% and 13% of cases, respectively.

There are few descriptions of the presence and analysis of developing complications in the literature found. Only early complications were mentioned. The most common ones include thromboembolic complications, urinary tract infections, pneumonia, and bedsores. Comparative analysis cannot be performed because of high heterogeneity. Evaluation of postoperative complications is also a challenge. Their incidence ranges 2.1% to 40.0%. This issue requires further research.

It should be mentioned that the pool of reviewed publications is limited to 2016. Considering the development of military science and delivery means of damaging components during the last 3–5 years, it can be assumed that present-day military conflicts will lead to further changes in the profile and epidemiology of combat-related spinal injuries. This, in turn, may require the appropriate planning of multi-directional medical care for such patients, including organizational and medical care, rehabilitation, social and psychological care; all this should become the issue of further research.

Table 8
Types of performed neurosurgical treatment

Author	Year	Patients, *n*	Neurosurgery		Stabilization, % of all surgeries		Decompression, % of all surgeries	
			%	*n*	%	*n*	%	*n*
Blair et al. [7]	2012	502	32.47	163	77.91	127	60.12	98
Possley et al. [1]	2012	591	31.13	184	NA	NA	NA	NA
Blair et al. [18]	2012	598	30.43	182	79.12	144	59.34	108
Mean value		–	31.35	–	78.55	–	59.71	–

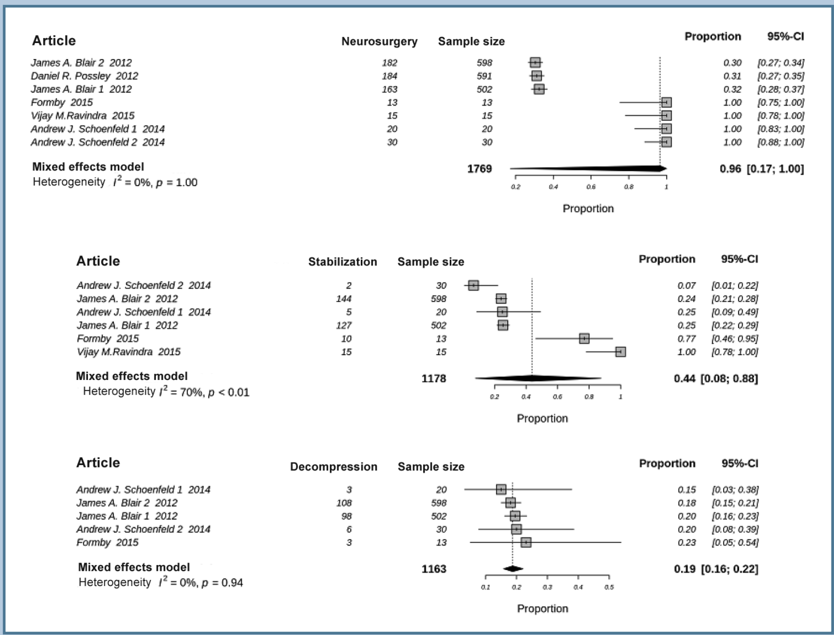

Fig. 10
Meta-analysis of performed neurosurgeries: in large cohort studies, 30–32% of patients received neurosurgical treatment; stabilization was performed in 43.68% of patients (95% CI: 7.88–87.55%; $I^2 = 70\%$; $p < 0.01$), decompression of the spinal cord and roots – in 18.74% (95% CI: 15.77–22.13%; $I^2 = 0\%$; $p = 0.94$)

The study had no sponsors. The authors declare that they have no conflict of interest.
The study was approved by the local ethics committees of the institutions.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

Table 9
Types of performed neurosurgical treatment

Authors	Patients, n	Day of surgery	Surgeries		Stabilization and decompression		Stabilization only		Stabilization type							Decom-pression only	Sealing of the dura mater	
									Posterior fixation		Anterior fixation		Circumferential fixation					
			%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Formby et al. [13]	13	1,6	100	13	0.00	0	76.92	10	61.54	8	7.69	1	7.69	1	23.08	3	38.46	5
Ravindra et al. [14]	15	NA	100	15	0.00	0	100.00	15	66.67	10	26.67	4	6.67	1	NA	NA	NA	NA
Schoenfeld et al.	20	3	100	20	60.00	12	25.00	5	75.00	15	5.00	1	20.00	4	15.00	3	NA	NA
[15]	30	0,8	100	30	73.33	22	6.67	2	76.67	23	3.33	1	NA	NA	20.00	6	NA	NA

Table 10
Complications

Author	Year	Patients, n	Complications, n	Thrombosis	PE	Urinary tract infection	Bedsores and pneumonia	Post-surgical complications	Mortality	
									%	n
Formby et al. [13]	2016	13	18	4	3	11	–	–	–	–
Ravindra et al. [14]	2016	15	–	–	–	–	–	–	–	–
Schoenfeld et al. [15]	2014	20	4	2	–	–	3	4	–	–
		30	12	2	–	–	5	12	–	–
Schoenfeld et al. [3]	2012	29	–	–	–	–	–	–	10.34	3
Szuflita et al. [6]	2016	206	–	–	–	–	–	–	4.85	10
Possley et al. [1]	2012	591	55	12	3	3	31	13	0.34	2
Blair et al. [18]	2012	598	–	–	–	–	–	–	2.84	17

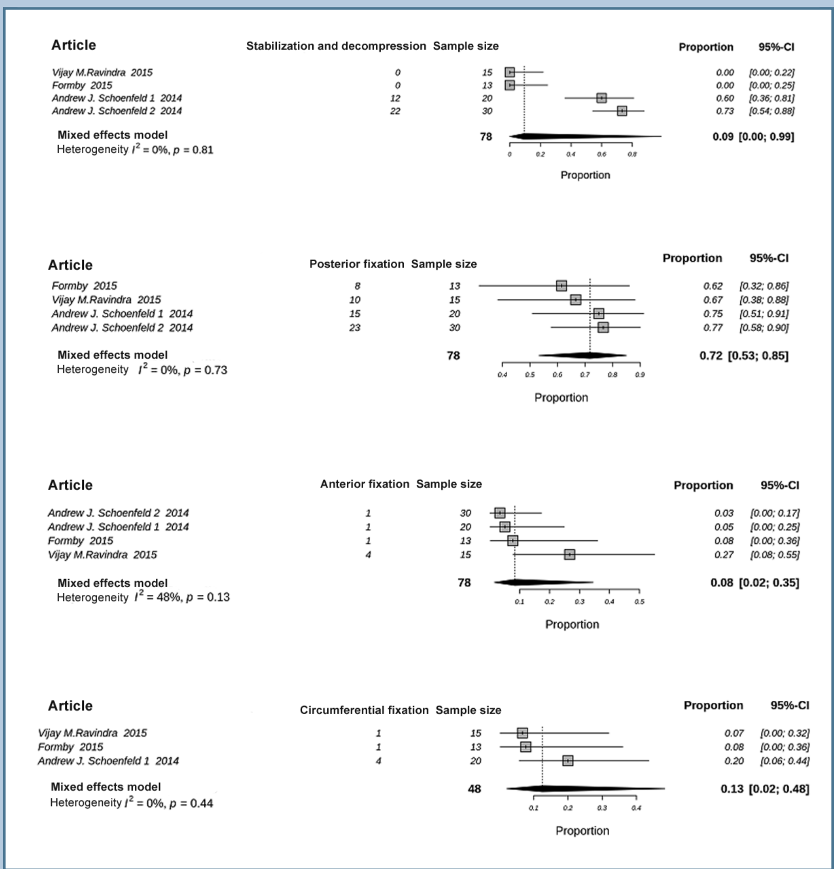

Fig. 11
Meta-analysis of spinal stabilization surgeries: stabilization and decompression were observed in 9.37% of patients (95% CI: 0.01–98.74%; $I^2 = 0\%$; $p = 0.84$), posterior fixation – in 72.0% (95% CI: 53.33–85.01%; $I^2 = 0\%$; $p = 0.73$), anterior fixation – in 8.0% (95% CI: 1.55–34.54%; $I^2 = 48\%$; $p = 0.13$), circumferential fixation – in 12.5% (95% CI: 2.14–48.3%; $I^2 = 0\%$; $p = 0.44$)

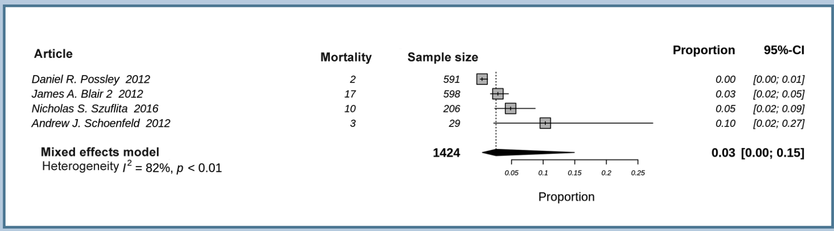

Fig. 12
Meta-analysis of mortality in patients with spinal cord injury (see the symbol legend to Fig. 2)

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