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TOPICAL ASPECTS OF COMBINED COMBAT THERMOMECHANICAL INJURIES

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Severe mechanical injuries and large and deep burns lead to burn and wound shock, which is more severe than in isolated mechanical wounds and burns. The key syndrome in the pathogenesis of shock named hemocirculation disorders syndrome is formed as a result of blood and plasma loss, including losses caused by burn wounds. In medical evacuation of the wounded persons with severe and extremely severe combined injuries, there is a tendency to accelerate the transportation of the wounded persons to the next stage as fast as possible, and sometimes the severity of injuries is not taken into account, which leads to deterioration in the condition of the wounded persons. There was a comparative integrated clinical examination of 183 injured persons, who were divided into 3 groups. Group 1 consisted of 71 wounded persons with combat extremity injuries, Group 2 consisted of 61 persons with minor injuries, and Group 3 consisted of 57 persons with severe and extremely severe injuries.

Key words: combined combat thermomechanical injury, wound shock, shock.

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АКТУАЛЬНІ АСПЕКТИ КОМБІНОВАНОЇ БОЙОВОЇ ТЕРМОМЕХАНІЧНОЇ ТРАВМИ

При важких механічних ушкодженнях і великих та глибоких опіках розвивається опіковий і травматичний шок, який протікають важче, ніж при таких ізольованих механічних ушкодженнях та опіках. Формування ключового у патогенезі шоку синдрому гемоциркуляторних порушень відбувається внаслідок крововтрати та плазмовтрати, в тому числі з опікових ран. На шляхах медичної евакуації поранених з тяжкими та вкрай тяжкими комбінованими травмами спостерігається тенденція до прискорення транспортування поранених на наступний етап, як можна раніше, іноді не враховуючи тяжкість, що призводить до погіршення стану поранених. Проведено порівняльне комплексне клінічне обстеження 183 постраждалого, які були поділенні на 3 групи. Група 1 становила 71 поранених з бойовими травмами кінцівок, група 2 становила 61 постраждалих з не тяжкою, група 3 становила 57 постраждалих з тяжкою та вкрай тяжкою.

Ключові слова: комбінована бойова термомеханічна травма, травматичний шок, шок.

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Modern man-made disasters and emergencies are characterized not only by multiple and combined injuries, but also by a high severity of injuries [1, 2]. Thermomechanical injuries are observed in the majority of cases of combined trauma, which in the general structure of peacetime trauma experience accounts for up to 1 % of the injured persons, and in the military one – up to 5–10 % of the injured persons [3]. When nuclear weapons were used in Japan (Nagasaki, Hiroshima, 1945), the share of combined injuries was 85 %, where 42.4 % were thermomechanical injuries [4]. The local wars in Korea and Vietnam resulted in 20–27 % of the wounded suffering napalm burns combined with gunshot wounds [5].

This category of injured people is characterized by the particular severity of their condition and the complexity of diagnostics and treatment. Severe combined injuries lead to the development of decompensated (critical) conditions in the early period after wounding with high mortality – 75–80 %. The experience of the Vietnam War revealed that the largest number of irreplaceable combat losses was found in gunshot wounds combined with burns [6].

Severe mechanical injuries and large and deep burns result in burn shock (BS) and wound shock (WS), which are more severe than in the case of similar isolated mechanical injuries and burns. The key syndrome in the pathogenesis of shock named hemocirculation disorders syndrome is formed as a result of blood and plasma loss, including losses caused by burn wounds.

In combined combat thermomechanical injuries (CCTMI), the incidence of BS and WS ranges from 11.3 % to 85.9 %. In the case of combined injuries, anatomic severity scale for injuries, burns and wound shocks do not correspond to each other and depend on the particular healing capacities of the body, the timeliness and quality of the anti-shock measures. In 16.7 % of cases, the degree of irreversible pathophysiological changes in BS and WS is not characterized by early clinical symptoms due to inconsistency in combined gunshot wounds severity anatomic score. The diagnostics and determination of the severity degree of WS and BS at the Level II stage of medical evacuation (SME) are based on the general condition, hemodynamic parameters and respiratory rate. At the same time, it is known that systolic blood pressure in the early stages of WS and BS does not show the whole scope of pathological processes and often does not change.

In medical evacuation of the wounded persons with severe and extremely severe CCTMI, there is a tendency to accelerate the transportation of the wounded persons to the next SME as fast as possible, and sometimes the severity of injuries is not taken into account, which leads to deterioration in the condition of the wounded persons.

Thus, the priority task of the battlefield surgery is to develop a system of quantitative assessment of the severity of gunshot injuries, which will allow objectifying treatment and evacuation tactics of the wounded with CCTMI in the acute period of traumatic and burn diseases.

The purpose of the research was to substantiate evacuation schemes for the wounded, to determine the interrelated parameters of vital body systems during the shock period associated with combined injuries, as well as to develop an anatomic and functional model of wound and burn shocks severity.

Materials and methods. The research was carried out in three stages: at the 1st stage, the most informative homeostasis indicators reflecting the severity of WS and BS were identified; at the 2nd stage, criteria for assessing the severity of WS and BS were determined and selected; at the 3rd stage, WS and BS effect prediction system was developed.

There was a comparative integrated clinical examination of 183 injured persons, who were divided into 3 groups. Group 1 consisted of 71 wounded persons with combat extremity injuries (CEI), Group 2 consisted of 61 persons with minor CCTMI, and Group 3 consisted of 57 persons with severe and extremely severe CCTMI.

The examination covered the recording of integral body rheography (IBR) according to Tyshchenko M. I., study of coagulation tests results, general clinical, biochemical, immunological blood indicators at admission on 1–3 and 5–7 days after the injury.

IBR was recorded according to the generally accepted methodology at a frequency of 30 kHz using the KSVG – 1 apparatus.

The calculation of scores for the assessment of WS and BS severity and WS and BS effect prediction was made using a personal computer, and the results were obtained in five minutes.

To assess the injury severity at the SME, the following scales developed by the staff of the Department of Military Surgery of the Ukrainian Military Medical Academy were used: Admission trauma scale (AdTS), anatomic and functional index (AFI) and condition severity index based on multivariate analysis (MVA). These methods are characterized by their versatility, the ability to assess the severity of open and closed injuries and high statistical reliability according to the survival-to-death ratio of 89 %.

Results of the study and their discussion. Based on the clinical and statistical analysis performed for the wounded with severe CCTMI (5-9 points acc. to AdTS), at admission to the Level II SME in group 1 and group 2 there were statistically significant changes in 21 (80.77 %) homeostasis indicators out of 26, as compared to the control group ($p<0.05$). The integrated injury severity AFI (group 1–616.39±6.32 points; group 2–625.80±7.07 points) and condition severity index based on MVA (group 1–0.16±0.02

points, group 2–0.19±0.03 points) during TD and BD showed severe CCTMI with a questionable prognosis for survival of the wounded at the Level II SME.

At admission to the Level II SME, the wounded with severe CCTMI had severe respiratory and circulatory disorders (respiratory and circulatory disorders severity index = 5.19±0.63 RU for group 1 and 5.21±0.69 RU for group 2) due to a moderate 32 % decrease in one-time cardiac efficiency (stroke volume index = 32.15±3.56 ml/m2 for group 1 and 33.18±4.22 ml/m2 for group 2), 23 % decrease in cardiac output (cardiac index = 3.25±0.11 l/min/m2 for group 1 and 3.21±0.13 for group 2), and acute external respiratory failure (group 1: respiratory rate = 20.89±0.72 /min; respiratory changes factor = 1.54±0.06 RU; respiratory tension index = 32.17±2.10 RU; group 2: respiratory rate = 22.59±0.79 /min; respiratory changes factor = 1.51±0.07 RU; respiratory tension index = 34.10±2.17 RU). Respiratory and circulatory disorders compensation in the wounded with severe CCTMI was achieved by increasing the heart rate by 60 % (108.07±3.11 beats/min for group 1; 109.12±4.02 beats/min for group 2) and moderate arrhythmia (vascular tone stabilization index = 1.11±0.01 RU).

Group 1 and group 2 showed moderate centralization of blood circulation associated with hypotension (integral tonicity factor = 79.77±1.91 RU; systolic BP = 82.75±1.71 mm Hg, and integral tonicity factor = 80.14±2.03 RU; systolic BP = 83.70±1.82 mm Hg, respectively).

The wounded with severe CCTMI had post-traumatic anemia, with moderate blood loss of up to 1 liter with CBV deficiency of up to 20 %, moderate neutrophilia (6.10±0.44 % for group 1; 6.08±0.43 % for group 2), hyperglycemia (7.54±0.21 mmol/L for group 1; 7.62±0.21 mmol/L for group 2) and decreased total blood protein.

At the Level III SME the significant changes in 20 (76.92 %) out of 26 homeostasis indicators were detected in groups 1 and 2. In group 3, there were significant changes in 23 (88.46 %) indices. The integrated injury severity AFI and condition severity index based on MVA demonstrated the severe nature of injuries with a questionable prognosis for survival of the wounded. In particular, there was a significant decrease in the integrated injury severity AFI in group 1 and group 2 (583.00±4.46 points and 606.52±7.92 points, respectively) as compared to group 3 (630.35±9.04 points). These changes are due to the fact that group 3 wounded persons were not provided with the Level II medical care ($p<0.05$). The Allgower index was significantly increased (group 1–0.80±0.02 RU; group 2–0.87±0.04 RU; group 3–1.13±0.09 RU). However, it decreased by 38.46 % in group 1 and by 33.08 % in group 2 as compared to the previous SME. The Allgower index was increased by 29.89 % in group 3 as compared to group 1 and group 2 ($p<0.05$) [7].

There were respiratory and circulatory disorders in comparison groups (respiratory and circulatory disorders severity index = 3.12±1.09 RU for group 1; 4.89±1.03 RU for group 2; 5.36±0.27 for group 3). Specific features were the tendency to increase the specified indicator in group 1 due to changes in one-time cardiac efficiency and cardiac output over time (stroke volume index = 38.73±1.87 ml/m2; cardiac index = 3.96±0.12 l/min/m2).

At admission to the Level III SME, group 3 wounded persons with severe CCTMI had severe respiratory and circulatory disorders due to decreased one-time cardiac efficiency and cardiac output with further development of circulatory failure (stroke volume index = 22.96±3.42 RU; cardiac output = 4.67±0.73 l/min, cardiac index = 2.16±0.15 l/min/m2; reserve ratio = 76.17±6.05 %) and dyshidrosis associated with inadequately controlled blood loss (balance index = 0.85±0.04 RU).

The comparison groups at the SME showed moderate tension of external respiration compared to the control group ($p<0.05$) [8].

Respiratory and circulatory disorders compensation in the wounded with severe CCTMI in group 1 and group 2 was achieved by increasing the heart rate by 28.02 % (86.89±2.02 beats/min for group 1; 85.89±2.23 beats/min for group 2) and moderate arrhythmia (vascular tone stabilization index = 1.10±0.01 RU for group 1; vascular tone stabilization index = 1.12±0.01 RU for group 2).

Comparison group 1 and group 2 showed moderate centralization of blood circulation associated with hypotension (integral tonicity factor = 77.13±1.84 RU; systolic BP = 108.72±2.01 mm Hg, and integral tonicity factor = 79.89±2.44 RU; systolic BP = 98.59±2.91 mm Hg, respectively).

Among wounded persons with severe CEI in group 3, 61.57 % increase in heart rate (108.40±3.12 beats/min) did not lead to respiratory and circulatory disorders compensation in comparison with the control group. In 3 wounded persons who died, integral tonicity factor and systolic BP demonstrated unidirectional changes toward hypotension (integral tonicity factor = 72.13±2.55 RU; systolic BP = 95.62±3.61 mm Hg).

The wounded with severe CEI at the Level III SME had moderate post-traumatic anemia, with moderate blood loss of up to 1 liter and CBV deficiency of up to 20 %. Group 1 and group 2 wounded persons with severe CEI showed a 2-fold increase in stab neutrophils (6.07±0.35 % and 6.12±0.42 %, respectively), group 3 showed more than 3-fold increase (8.97±0.78 %) in comparison to the control group ($p<0.05$). Hyperglycemia and hypoproteinemia were observed in all comparison groups ($p<0.05$) [9].

For group 3, the integrated injury severity AFI and condition severity index based on MVA of the wounded with severe CEI at the Level III SME over the course of TD demonstrated progression of injury severity to extremely severe with a poor prognosis for 3 wounded persons who died. They were taken from the battlefield to the Level III SME: 2 of them had severe combined thigh gunshot wounds with femur multi-fragmental fractures, and 1 of them had severe combined mine-blast injury (MBI) and foot avulsion.

At the Level IV SME, the integrated injury severity AFI and condition severity index based on MVA showed a severe nature of the injuries with a questionable prognosis for survival of the wounded with CEI. In particular, there was a decrease in the integrated injury severity AFI for group 1 (544.77±4.62 points) and group 2 (555.04±3.86 points). As for group 3, there was an increase in AFI up to 603.68±8.34 points in the wounded who survived, and up to 643.43±9.85 points in the wounded who died ($p<0.05$) [10].

The Allgower index was regularized in group 1 and significantly increased in group 2 (0.72±0.03 RU). There was a significant decrease in the Allgower index by 21.25 % in group 1 and by 17.24 % in group 2 as compared to the Level III SME. The Allgower index in group 3 was 1.5 times higher than in the control group in survivors and 2.5 times higher in deceased persons (0.91±0.07 RU and 1.40±0.09 RU, respectively) ($p<0.01$).

In group 1 and group 2, mild respiratory and circulatory disorders were observed with a tendency to their regularization (respiratory and circulatory disorders severity index = 7.73±0.23 RU and 7.56±0.27 RU, respectively). There was a distinctive increase in the abovementioned index in group 1 and group 2 due to the regularization of one-time cardiac efficiency associated with the increase in the cardiac output over the course of the TD (group 1: stroke volume index = 42.52±3.73 ml/m2; cardiac index = 3.76±0.11 l/min/m2; cardiac output = 7.52±0.44 l/min; group 2: stroke volume index = 41.58±3.79 ml/m2; cardiac index = 3.66±0.10 l/min/m2; cardiac output = 7.50±0.35 l/min).

The wounded in group 3 experienced severe changes in respiratory and circulatory disorders due to a decrease in one-time cardiac efficiency and cardiac output with further progression of circulatory failure in the wounded who died (group 3, wounded survivors: stroke volume index = 34.53±4.05 ml/m2; cardiac index = 3.56±0.24 l/min/m2; group 3, wounded persons who died: stroke volume index = 18.96±4.11 ml/m2; cardiac index = 2.05±0.25 l/min/m2; cardiac output = 4.59±0.23 l/min, reserve ratio = 81.14±4.66 %) and dyshidrosis associated with inadequately controlled blood loss (balance index = 0.81±0.05 RU).

Group 1 and group 2 showed moderate tension of the external respiration, and group 3 showed a severe tension ($p<0.05$).

Respiratory and circulatory disorders compensation in group 1 and group 2 was achieved by a moderate increase in the heart rate by 14.32 % (76.70±2.47 beats/min for group 1; 79.13±2.07 beats/min for group 2) and moderate arrhythmia (vascular tone stabilization index = 1.14±0.01 RU for group 1; vascular tone stabilization index = 1.15±0.01 RU for group 2).

Respiratory and circulatory disorders compensation in wounded survivors with severe CCTMI in group 3 was achieved by increasing the heart rate by 47.49 % (98.95±2.02 beats/min) and moderate arrhythmia (vascular tone stabilization index = 1.10±0.01 RU).

However, an increase in heart rate by 61.57 % (110.52±4.81 beats/min) in the deceased wounded with severe CCTMI in group 3 did not result in respiratory and circulatory disorders compensation. In deceased wounded with severe CCTMI, integral tonicity factor and systolic BP demonstrated unidirectional changes toward hypotension (integral tonicity factor = 72.70±2.21 RU; systolic BP = 79.20±7.49 mm Hg).

At the Level IV SME, the wounded with severe CCTMI experienced a 2-fold increase in stab neutrophils in group 1 and group 2, and more than 3.5-fold increase in group 3 ($p<0.05$). All the groups had hyperglycemia at the Level IV SME. The wounded survivors in group 3 had a 33.84 % increase in the above index, and the wounded who died had an almost 2-fold increase ($p<0.05$). Hypoproteinemia was observed in group 3 in the wounded who died, the level of total blood protein was reduced by 27.80 % ($p<0.05$). Within the group 3, 3 wounded out of 16 injured persons with severe CCTMI had the integrated injury severity AFI and condition severity index (MVA) that at the Level IV SME over the course of TD and BD showed that the injury severity changed to extremely severe and the survival prognosis became poor, which led to their death. Two of them had combined gunshot femur fractures and torso burns, and one of them had lower-leg bones fractures and burns of both thighs.

Thus, the wounded persons in group 1 had gradual stabilization of homeostasis indicators after the medical care delivery at the previous stages and admission to the Level IV SME, group 2 demonstrated positive tendency of changes in the indicators to moderate ones, and the indicators in group 3 demonstrated severe disorders with a tendency to worsening, which resulted in 15 deaths of the injured persons.

Conclusion

Integral body rheography in combination with the AdTS scale for the assessment of the severity of combined injuries is the most reliable method for determining the severity and prognosis of wound and burn shocks.

Based on the clinical and statistical analysis performed for the wounded with severe combined combat thermomechanical injuries according to 26 homeostasis indicators, it was found that consistent delivery of medical care at the stages of medical evacuation by means of timely surgical treatment and anti-shock measures implementation associated with maintaining the body's functional reserves leads to improvement of the condition due to a gradual change in respiratory and circulatory disorders from severe to moderate ones.

Delivery of medical care to the wounded persons with severe combined thermomechanical injuries under the shortened evacuation scheme leads to deterioration in the condition of the wounded to extremely severe and irreversible respiratory and circulatory changes associated with the decrease in one-time cardiac efficiency and cardiac output with further cardiovascular insufficiency and respiratory failure.

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