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Rīgas Stradiņa Universitāte

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EVALUATION OF THE FUNCTIONAL OUTCOME OF POLYTRAUMA PATIENTS WITH MUSCULOSKELETAL INJURIES

Summary of the Doctoral Thesis
for obtaining the degree of a Doctor of Medicine
Specialty – Traumatology and Orthopaedics

Riga, 2014

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Thesis was developed in the Rīga Stradiņš University in co-operation with National Rehabilitation Center "Vaivari", Riga Eastern Clinical University Hospital, Clinic "Gailezers", Trauma and Orthopaedic Department, and Hospital of Traumatology and Orthopaedics

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The Doctoral Thesis is available in the library of RSU and on the RSU home page: www.rsu.lv

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Secretary of Doctoral Council:

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LIST OF ABBREVIATIONS

AIS – Abbreviated injury scale

AO – germ. *Arbeitsgemeinschaft für Osteosynthesefragen*

ATLS –Advanced trauma life support

DCO – Damage control orthopaedics

GC – gait cycle

GD – gait deviation

GRF – ground reaction force

GRF A – maximal anterior ground reaction force in terminal stance

GRF P – maximal posterior ground reaction force in loading response

GRF V1 – maximal vertical ground reaction force in loading response

GRF V2 – maximal vertical ground reaction force in terminal stance

IGA – three dimensional instrumental gait analysis

ISS – Injury severity score

NISS – New injury severity score

P – Independent Samples T test (P value)

ROM – range of motion

RRL, NRC „Vaivari" – Rīga Stradiņš University Faculty of Rehabilitation Rehabilitation Research Laboratory, National Rehabilitation Centre „Vaivari"

RSU – Rīga Stradiņš University

SD – standard deviation

INTRODUCTION

Characteristics of the study

A significant number of patients with multiple injuries is annually registered in Latvia. According to the data of the Health Economics Centre of Latvia (22.03.2011.), 382 patients with multiple trauma were registered in 2008, 573 patients in 2009, 582 patients in 2010. In most cases the cause of the multiple trauma were traffic accidents and falls from hight. Since the legislation in Latvia does not impose the determination of trauma severity according to Injury severity score (ISS) and New injury severity score (NISS), definition of polytrauma, based on ISS and NISS, there is no common registration system of polytrauma patients and the exact number of polytrauma patients in the hospitals of Latvia during the year is not known. The term „polytrauma" in some hospitals in Latvia is used when a patient has two or more injuries which can endanger the patient´s life. One of the most commonly used is the one by European Trauma and Emergency Surgery Association´s sixth president professor of Zurich Trauma University Otmar Trentz. Polytrauma is defined as a syndrome characterized by multiple injuries exceeding a defined severity grade (ISS ≥17) with sequential systemic reactions that may lead to dysfunction or failure of remote organs and vital systems, which have not been directly injured. (1) Polytrauma is caused by high energy. Knowledge about pathogenesis of polytrauma gives a possibility to understand early and late causes of complications of musculoskelatal system. The actual problem is the determination of trauma severity and identification of medium-term functional outcome for patients after polytrauma. Injury severity affects both mortality and final functional outcome. Major improvements in the management of severely injured patients in the past decades have led to a significant reduction of polytrauma associated mortality. (2) Therefore the is a constant problem of improvement of functional recovery of patients after severe musculoskeletal injuries. Polytrauma patients who have associated orthopedic injuries face greater challenges regarding functional recovering. (3) Patients who have complex foot injuries, articular fractures, major nerves damaged and complete ligament injuries to the lower extremities have serious medium-term impaired function in the lower extremities regardless of low ISS score because ISS is the sum of the squares of the highest Abbreviated injury scale (AIS) scores in three different ISS body regions. To improve injury severity evaluation of polytrauma patients, especially with orthopaedic injuries, ISS was modified and NISS developed, which is the sum of the squares of the three highest AIS scores regardless of the body region. Thus, NISS gives a possibility to evaluate the severity of injuries and prognosis of the result of polytrauma patients with orthopaedic injures. (4)

Primary survey in the prehospital stage and in the hospital emergency departament is the obligatory measure to diagnoze early and accordingly treat injuries. In patients who have high energy caused injuries of extremities is very important the choice of primary surgery and its quality that determine the long-term result. Often the priority is another urgent surgery thus early and proper orthopaedic operations according to the principles of damage control orthopaedics (DCO) are not performed. (5) The teams who treat polytrauma patients in hospitals receive limited information about the late disabilities after multiple injuries. (6) We evaluated polytrauma patients during the period of 12 to 41 months after trauma. The sooner this evaluation is performed the more success in the correction of lower limb functional abnormalities is possible. (7)

Performing analysis of retrospective material, we have found that diagnosing polytrauma common criteria of ISS and NISS for the polytrauma definition are not used. Severity of patients with multiple trauma is evaluated differently. In the Orthopaedic Chair of Rīga Stradiņš University the knowledge and practical skills in primary survey (ABCDE) algorithm ISS, NISS criteria and DCO are included in the study course. Using primary survey decreases not diagnozed injuries and functional limitations connected with undiagnozed orthopaedic injuries. (8) Therefore early and proper examination of the extremities during the primary survey in the early stage after polytrauma is very important, regardless of the severe condition of the multiple trauma patients. Nevertheless, during our study we have noticed that many doctors are poorly informed about primary survey, criteria of polytrauma, significance of DCO principles in the treatment of polytrauma patients and in their recovery. Not always primary survey is performed immediately after the multiply injured patient is addmitted to the hospital emergency department and in the nearest period after trauma, which can lead to undiagnozed injuries, especially of extremities, and late complications due to the consequences of undiagnozed fractures and dislocations. We also noticed that after check-out of hospital not always is the functional outcome of musculoskeletal system of patients after multiple injuries regularly and sistematically evaluated and analyzed.

Evaluation of the functional outcome of musculoskeletal system is important, because patients′ life quality and returning to previous work depends on it. Prompt diagnosis and treatment of functional abnormalities of patients after polytrauma are very important. Analysis of the functional outcome gives a possibility to plan more precisely the finansial needs in the treatment of polytrauma patients and economy of finansial resources. Clinical and instrumental examination methods can be used to evaluate the functional results of polytrauma patients with orthopaedic injuries. To assess the functional result of polytrauma patients with lower limb injuries we used clinical examination and three dimensional instrumental gait analysis (IGA). Instrumental gait analysis is an objective instrumental examination method which is used to examine all phases of gait cycle (GC) and identify causes of gait deviations (GD). Evaluation of functional limitations of lower extremities in the medium-term after polytrauma gives a possibility to evaluate the connection between trauma severity and treatment, as well as plan rehabilitation measures.

Study theme is actual because it refers to doctors of different specialities who treat polytrauma patients and provide their rehabilitation.

This study analyzes functional outcome of lower extremities in 1–3 years follow-up of polytrauma patients who suffered severe lower limb injuries. We determined polytrauma severity, relation between ISS, NISS and GD severity. We compared the data with clinical orthopaedic examination and IGA parameters of healthy volunteers′ control group. We evaluated the relation among ISS, NISS and functional limitations.

Aim of the study

The aim of our study is to analyze functional outcome of patients after polytrauma with consequences of lower limb injuries.

Objectives of the study

1. To perform the retrospective material analysis of polytrauma patients with musculoskeletal injuries treated in two Riga hospitals − Riga Eastern Clinical University Hospital, Clinic „Gailezers”, Trauma and Orthopaedic department and Hospital of Traumatology and Orthopaedics during 2008−2010 years´ period.
2. To calculate ISS and NISS for these patients and determine polytrauma severity.
3. To perform the clinical orthopaedic examination, radiological examination and IGA of patients with consequences of lower limb injuries in the medium-term (1–3 years) after polytrauma.

4. To analyse GC parameters of healthy volunteers control group obtained in IGA.
5. To analyze the results, estimate GD severity, give recommendations for the improvement of the functional outcome obtained in IGA.
6. To compare the clinical examination data of patients and healthy volunteers.
7. To compare IGA spatio-temporal, motions in the pelvis, hip, knee, ankle and subtalar joints and ground reaction force (GRF) parameters of polytrauma patients and healthy volunteers.
8. To compare IGA spatio-temporal, motions in the pelvis, hip, knee, ankle and subtalar joints and GRF parameters in polytrauma patients with articular and extraarticular fractures.
9. To compare IGA spatio-temporal, motions in the pelvis, hip, knee, ankle and subtalar joints and GRF parameters of uninjured extremity of polytrauma patients with unilateral injuries and healthy volunteers.
10. To compare polytrauma severity with GD severity and find out if there is relation between ISS, NISS and the functional outcome and work out proposals (algorithm) for the evaluation of polytrauma patients with lower limb injuries and prognosis of functional outcome.

Hipothesis of the study

Polytrauma patients with consequences of lower limb injuries have not only primary, but also secondary (compensatory) functional limitations of pelvis and lower extremities in the uninjured side which correspond with polytrauma definition. It is possible to prognoze functional result in polytrauma patients with musculoskeletal injuries using NISS.

Scientific novelty of the study

The scientific novelty of the study is that in this study first time in Latvia is analyzed the functional outcome of polytrauma patients with lower extremities injuries consequences in the medium-term after trauma, by using IGA, and studied the relation among ISS, NISS and functional limitations. New data has been obtained about functional outcome of polytrauma patients with consequences of lower extremities injuries and the possibilities of its prognosis. We have found secondary (compensatory) functional limitations of pelvis and lower extremities in the uninjured side.

Personal contribution of the author

The author personally performed all stages of study – planning of the study, collection of the retrospective material, clinical examination of the patients, IGA, analysis, interpretation, description of the obtained results, development of conclusions and proposals for the patients, data collection, statistical anlysis, IGA obtained data collection and statistical anlysis of the control group, is the author of scientific publications and presentations of congreses, conferences and photos, presented in the thesis.

Structure of the thesis

The thesis is written in the Latvian language. It consists of introduction, literature study, study of materials and methods, results, discussion and conclusions. It has 10 supplements. The amount of thesis is 127 pages. One hundred forty-three authors´ publications are analysed in the thesis.

There are 4 scientific publications about thesis theme, 1 patent, 16 abstracts published, 13 oral presentations given as well as 2 posters at congreses and conferences.

1. MATERIALS AND METHODS

1.1. Definitions used in the study

1. **Abbreviated injury scale (AIS)** – injury severity coding system, where injuries are coded according to the six AIS severity codes: minor, moderate, serious, severe, critical and maximal (currently untreatable) (*Association for the Advancement of Automotive Medicine, 2008*).

2. **Damage control orthopaedics (DCO**) – treatment tactics of polytrauma patients with orhopaedic injuries, wich are based on primary stabilization of long bone fractures, using external fixation (*Pape HC, 2010*).

3. **Injury severity score (ISS)** − sum of the squares of the highest AIS scores in three different body regions (*Association for the Advancement of Automotive Medicine, 2008*).

4. **New injury severity score (NISS)** − sum of the squares of the three highest AIS scores anywhere in the body (*Association for the Advancement of Automotive Medicine, 2008*).

5. **Polytrauma** − syndrome characterized by multiple injuries exceeding a defined severity grade (ISS ≥17) with sequential systemic reactions that may lead to dysfunction or failure of remote organs and vital systems, which have not been directly injured (*Trentz O, 2007*).

6. **Primary survey (ABCDE algorithm)** – systematic and rapid evaluation of trauma patient, to identify all life threatening injuries and treat until next stage (*American College of Surgeons, 2012*).

7. **Three dimensional instrumental gait analysis (IGA)** − an examination method, during which quantitative information about the movements of body segmants is collected during GC with the aim to understand the origin of GD and to find the ways of its prevention (*Medical technologies data base, used in medicine, Latvia*).

1.2. Selection of patients

A retrospective study of 154 polytrauma patients treated after severe musculoskeletal injuries in two Riga Hospitals (Riga Eastern Clinical University Hospital, Clinic „Gailezers", Trauma and Orthopaedic department and Hospital of Traumatology and Orthopaedics) during the years 2008–2010, was performed.

Out of the retrospective study group, patients aged 18–60 were enrolled for the functional outcome study if they fulfilled the inclusion criteria.

The inclusion criteria:

1. 18–60 years of age;
2. at least one lower extremity injury;
3. no lower limb amputation;
4. no spine trauma with neurological complications;
5. no documented psychiatric diseases;
6. patient aggrees to participate in the study.

The exclusion criteria:

1. inability to walk barefoot a distance of 7–8 meters 6 times;
2. patient has non-union of lower extremities fractures;
3. patient had brain trauma which caused functional limitations of the musculoskeletal system;
4. patient had lower extremities trauma or diseases before polytrauma which caused functional limitations;
5. patient had lower extremities trauma after polytrauma;
6. patient has chronic osteomyelitis;
7. patient did not respond to three phone calls and the letter;
8. patient moved to another country.

The lower extremity injuries in our study were defined as pelvic fracture, hip dislocation, femoral fracture, tibial or fibular fracture, knee dislocation, ankle joint or complex foot injury. (9)

The patients were recruited according to their residences from the hospital case-records of the patients. The patients who corresponded inclusion criteria were invited to undergo the evaluation of functional outcome by a phone call or a letter that described the purpose of the study and the IGA method.

The study was conducted on 34 polytrauma patients with orthopaedic injuries. Evaluation of the functional outcome was performed in the Rīga Stradiņš University Rehabilitation Research Laboratory, located in the National Rehabilitation Centre „Vaivari" (RRL, NRC „Vaivari").

There were two study groups: polytrauma patients group and healthy volunteers control group.

The patients' complaints, clinical orthopaedic examination, radiological examination and IGA were included in the evaluation of functional outcome. For every patient ISS and NISS values were calculated. We determined the injured or most injured and the uninjured or less injured lower extremity. NISS values were used to evaluate the severity of polytrauma injuries because ISS does not give objective information about the amount of work and resources that are required if the patient has serious multiple injuries in one of the ISS anatomic regions, particularly orthopaedic injuries.

Clinical examination and IGA data of 34 healthy volunteers (24 women and 10 men; age range 19–65, mean age 36.38 years) for the control group was collected from RRL, NRC „Vaivari" volunteers data basis. IGA data were analyzed with Visual 3-D software program.

Patients and the control group data were summerized and analyzed with SPSS program. Clinical and IGA examination data were compared with the control group data.

To find out if the fracture type influences CG parameters, we divided study group patients in to two subgroups – patients with articular fractures and with extraarticular fractures in the injured or more injured side according to the fracture types determined by AO classification.

To find out if there were compensatory changed GC parameters in the uninjured side, we compared time, distance, kinematic and kinetic parameters of the uninjured extremity of polytrauma patients from study group with unilateral injuries of lower extremities and the control group.

Polytrauma severity was defined in the study. In the definition of polytrauma severity we used NISS based on the AIS codes. New injury severity score 17–26 were defined as polytrauma with moderate injuries, NISS 27–35 as polytrauma with serious injuries, NISS 36–49 as polytrauma with severe injuries, and NISS 50–66 as polytrauma with critical injuries.

1.3. Clinical orthopaedic and radiological examination

The patients' complaints were examined. Patients were asked to evaluate pain in their lower extremities according the following variables: „no pain", „moderate pain" or „severe pain".

Visual examination of the posture, gait, lower extremities and foot archs were performed. Movements in the joints were measured using goniometric technique. Muscle power was evaluated using 5 grades scale (*Medical Research Council scale for Muscle Strength*). Length and girth of the extremities were examined using type. Neirovascular examination of the extremities was performed. Radiological examination (consolidation stage of the fractures, bone structure, bone fragment position and nearest joints condition) was performed. Patients, who had talar neck fractures, were examined, using „Method of prognosis of avascular necrosis of the talar neck fractures" (LR patent). Hip, knee, ankle and subtalar joint movements and mucle power parameters obtained in the clinical examination were compared with the parameters of the control group mentioned before.

1.4. Instrumental gait analysis

After clinical and radiological examination patients underwent IGA. In Latvia IGA is available only in the RRL, NRC „Vaivari".

Instrumental gait analysis was performed using infrared light ProReflex MCU (240 Hz) digital cameras (Qualisys Medical, Sweden), force plate (Advanced Mechanical Technology, Inc., Watertown, USA) and Visual 3-D software developed in the National Health Institute, USA (C-motion Inc, USA). Light, spherical, reflective markers (19 mm) were attached to the skin to identify bony landmarks (the first sacral vertebra, both anterior superior iliac spinae, lateral surfaces of femur and shin, the heads of the first and the fifth metatarsal bones and the calcaneal bones). The patients had to walk barefoot a distance of 7–8 meters, 6–10 times at a self selected speed. The spatial coordinates of markers′ were registered during gait recording and the markers motion trajectories were calculated (Fig.1.1.). The patient had to put one foot on the force plate on the floor that registered GRF. (10)

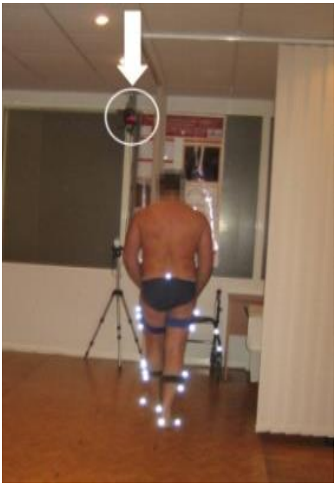

Fig. 1.1. Digital infrared light camera registers the markers′ motions, attached in the definite anatomical landmarks during gait cycle (photo from the author′s archive)

With two digital video cameras the visual gait recording was obtained. The findings were processed with data processing programs in the form of diagrams and numbers. The motion parameters of the pelvis and lower extremity joints during the gait were shown in the diagrams. The force moment of the muscles, the amount of generated and absorbed energy was shown in the diagrams in the sagittal and frontal plane. The spatio-temporal parameters of the GC were registered in the form of numbers.

The spatio-temporal parameters, motions in pelvis and the joints of lower extremities in sagittal and frontal plane, anterior, posterior and vertical load GRF of the GC of patients in the injured or more injured and uninjured or less injured lower extremity were analyzed. We defined GC parameters used in our study.

Gait parameters of the polytrauma patients' lower extremities were compared with the corresponding lower extremities gait parameters of the control group.

The patients received the IGA description, based on the clinical and IGA examination data.

The following patients´ group injured or more injured and uninjured or less injured lower extremity GC parameters were analyzed in the study:

1. GC spatio-temporal time parameters (cadence, stance time, gait speed, step lengh and step width);
2. according to the defined GC kinematic parameters:
   - 2.1. motions in pelvis and lower extremities joints in sagittal plane;
   - 2.2. motions in pelvis and lower extremities joints in frontal plane;
3. according to the defined GC kinetic parameters:
   - 3.1. anterior and posterior GRF;
   - 3.2. vertical load GRF during loading response and terminal stance.

Normal GC parameters were worked out using young healthy volunteers´ GC parameters, which corresponded also to the literature describing normal GC parameters. Phases of GC reflect functional parameters of lower extremities. (11)

Gait deviations severity was estimated as moderate GD, serious GD, severe GD and very severe GD according to the severity of changes of movements in the joints in the frontal and sagittal plane and the number of involved joints. Gait deviations severity was compared to polytrauma severity.

Data of protocols of polytrauma patients group and the control group were summarized in the SPSS programm, with which data analysis was performed.

The clinical examination and IGA data of polytrauma patients´ group were compared to the control group data.

For data summarizing SPSS program was used. Statistical analysis of the data was performed with SPSS 20.0 for Windows version. Study results were analyzed with descriptive statistics methods. To get quantitative data, means and SD were estimated. To compare polytrauma patients and healthy persons clinical examination and IGA data, two groups were selected in the study: a polytrauma patients group and a control group. Clinical examination and IGA data in the injured or more injured and uninjured or less injured lower extremity of the polytrauma patients were compared with mentioned data of the corresponding extremity of the control group by using Independent Samples T test. To find out if there are compensatory changes in the polytrauma patients´ uninjured lower extremity, a polytrauma patients group with unilateral injuries of lower extremities was selected. Clinical examination and IGA data of the uninjured lower extremity was compared with the control group by using Independent Samples T test. To compare the two dependent groups (ISS and NISS comparison in patients with different GD severity) Wilcoxon Signed Ranks test was used. P value<0.05 was considered significant.

2. RESULTS

2.1. Results of the retrospective material study of polytrauma patients with musculoskeletal injuries

A retrospective study of 154 polytrauma patients (53 women, 101 men), treated after severe musculoskeletal injuries (NISS≥17) in Trauma and Orthopaedic department, Clinic „Gailezers”, Riga Eastern Clinical University Hospital, (132 patients) and Hospital of Traumatology and Orthopaedics (22 patients) during the years 2008–2010 was performed. Trauma mechanisms were high energy trauma (road traffic accidents, fall from hight etc).

The patients had NISS 17–48, but ISS 9–48. Fifty-five patients (36%) had NISS equal to ISS, 99 patients (64%) had NISS higher than ISS. Forty-four patients had ISS lower than 17 (severity of trauma did not correspond the polytrauma definition).

In accordance with the exclusion criteria of the study 61 patient from the 154 patients retrospective analysis group was excluded: 24 patients had not lower extremities injuries, 27 patients did not correspond the age criteria of the study, 5 patients had lower extremity amputation, 5 patients had documented psychiatric diseases.

Ninety-three patients, who corresponded to the study inclusion criteria, were recruited according to their residences from the hospital case-records of the patients. They were invited to undergo the functional result evaluation by a phone call or a letter that described the purpose of the study and the IGA method. Out of 93 selected patients 18 patients did not respond to the phone calls, 19 patients did not respond to the letter, 13 patients refused to undergo the IGA, 7 patients moved to another country, 1 patient had had a fracture of proximal segment of tibia six months before recruitment and 3 patients could not walk the mentioned distance. These patients according to the exclusion criteria were excluded from this study.

2.2. Functional results of patients with consequences of lower limb injuries after polytrauma

2.2.1. Characteristics of patients

The study was conducted on 34 polytrauma patients (17 women and 17 men; age range 23–59, mean age 39.50±11.70 years) with consequences of lower limb injuries, 12–41 months after polytrauma, who corresponded to the study criteria. The patients had NISS mean 25.9, ISS mean 20.7. Instrumental gait analysis was performed in the RRL, NRC "Vaivari". Clinical orthopaedic examination and IGA data were compared to the control group. Fifteen patients had polytrauma with moderate injuries (NISS 17–26), 17 patients with serious injuries (NISS 27–35) and 2 patients had polytrauma with severe injuries (JISS 36–48).

2.2.2. Results of the clinical orthopaedic examination and radiological examination

Eight patients had no complaints about pain, 19 patients had moderate pain and 7 patients had severe pain during evaluation. Six patients had open fracture wound infection which was treated succesfully in all cases. Seventeen patients took a rehabilitation course in the rehabilitation center within six months after hospital discharge. Eighteen patients had true leg discrepancy in the injured side 1−3 cm. Thirty patients had delayed fracture healing. Out of those two patients had avascular necrosis of the femoral head 1−2 years after C type acetabular fracture, and the evaluation of the functional outcome for these patients was performed after total hip replacement. Two patients had non union (one patient with a fracture of the distal segment femur, one patient with a fracture of distal segment of tibia), and evaluation was performed after reoperation and fracture healing. Two patients had fracture healing in the average healing times.

We evaluated **motion in the joints** in the injured or more injured lower extremity and in the uninjured or less injured lower extremity of polytrauma patients group and the same side of the control group. The polytrauma patients in **the injured or more injured lower extremity** had decreased hip flexion, abduction, adduction, external and internal rotation, ankle flexion and extension, eversion in the subtalar joint ($P<0.05$). Two patients had knee joint flexion contracture, two patients had ankle joint flexion contracture (after deep peroneal nerve injury), one patient could not perform extension in the ankle joint. The polytrauma patients **in the uninjured or less injured lower extremity** had decreased hip extension, abduction, external and internal rotation, ankle flexion and extension ($P<0.05$). As knee extension mean value in the polytrauma patients group and the control group was 0, P value was not calculated.

We evaluated **muscle power** in the injured or more injured lower extremity and in the uninjured or less injured lower extremity of the polytrauma patients group and the same side of the control group. Muscle strength differed in the polytrauma patients group in **the injured or more injured lower extremity** and the control group: patient**s** had decreased muscle strength of hip flexors, extensors, abductors, adductors, external and internal rotators, knee and ankle flexors and extensors, inversion and eversion providing muscles in the subtalar joint ($P<0.05$). Muscle strength also differed in the polytrauma patients group in **the uninjured or less injured lower extremity** and the control group: patients had decreased muscle strength of hip flexors, extensors, abductors, adductors, external and internal rotators, knee and ankle flexors and extensors, inversion and eversion providing muscles in the subtalar joint ($P<0.05$). To find out, if the clinical orthopaedic examination parameters are significantly changed in the uninjured side, we compared the range of motion (ROM) in the joints and muscle power **in the uninjured side** of the patients **with unilateral injuries of lower extremities** with the same side of the control group. In the uninjured side there were significantly decreased hip extension, abduction, external and internal rotation, and ankle extension ($P<0.05$). These patiens had decreased muscle strength of hip extensors, abduction, adduction, external and internal rotators, knee flexors and extensors, ankle flexors and extensors, inversion and eversion providing muscles in the subtalar joint ($P<0.05$).

2.2.3. Results of instrumental gait analysis

We evaluated patients´ gait using IGA. We analyzed GC spatio-temporal, kinematic and kinetic parameters of the polytrauma patients and the control group.

The GC spatio-temporal parameters of the polytrauma patients group were significantly worse than the gait parameters of the same lower extremity of the control group: in the **injured or more injured** and in the **uninjured or less injured side** there was decreased cadence, increased stance time and decreased step lengths ($P<0.05$). The polytrauma patients also had decreased **walking speed** and **step width** in comparison with the control group ($P<0.05$).

The comparison of IGA **sagittal plane motion** results in the pelvis, hip, knee and ankle joints of the **injured or more injured lower extremity** in the polytrauma patients group with the same side lower extremity of the control group showed that polytrauma patients had significantly increased pelvic anterior tilt, a decreased hip extension and knee maximum flexion ($P<0.05$), but in the **uninjured or less injured** lower extremity in the polytrauma patients group in comparison with the same side lower extremity of the control group, polytrauma patients had significantly increased pelvic anterior tilt, decreased knee maxium flexion and increased knee minimum flexion ($P<0.05$).

The comparison of IGA **frontal plane motion** results in the pelvis, hip, knee and subtalar joints of the **injured or more injured** lower extremity in the polytrauma patients group with the same side lower extremity of the control group showed that polytrauma patients had increased pelvic drop in the stance and swing (P<0.05), but in the **uninjured or less injured** lower extremity in the polytrauma patients group in comparison with the same side lower extremity of the control group, polytrauma patients had decreased inversion in the subtalar joint (P <0.05).

The patients **in the injured or more injured side** and **in the uninjured or less injured side** in comparison with the control group in the same side had decreased anterior, posterior, vertical load **GRF** during loading response and terminal stance (P<0.05).

We divided the study group patients in two subgroups – patients with articular fractures and patients with extraarticular fractures in the injured or more injured side according to the AO fracture classification types. In the study group there were 21 patient with articular fractures and 13 patients with extraarticular fractures. We found out that patients with articular fractures had increased knee minimal flexion in comparison with patients with extraarticular fractures (P=0.05). Two patients in the articular fractures subgroup were not able to perform extension in the ankle joint and it remained in flexion during all GC. In this subgroup patients had decreased cadence, stance time, step length, increased pelvic anterior tilt, decreased GRF and the varus deformity of lower leg, but without significant difference.

We compared spatio-temporal, kinematic and kinetic parameters of the **uninjured extremity** of **26 polytrauma patients** from study the group, who had **unilateral injuries of lower extremities** and the control group. Polytrauma patients **with unilateral injuries in the uninjured side** had decreased step length, increased stance time and decreased cadence in comparison with the control group (P<0.05). The polytrauma patients had decreased walking speed and step width in comparison with the control group (P<0.05). Gait cycle **motion parameters** of pelvis, hip, knee and ankle joint in the **sagittal plane of the uninjured side in patients with unilateral injuries** displayed in table 2.1.

Table 2.1.

Sagittal plane motions in pelvis, hip, knee and ankle joints in the uninjured lower extremity of polytrauma patients and of the healthy control group during gait cycle

Parameter	Polytrauma group (n=26)		Control group (n=26)		P value
	Mean±SD(°)	n	Mean±SD(°)	n	
Pelvic anterior tilt	8.2±5.88	n=23	6.07±4.39	n=15	0.234
Pelvic posterior tilt	15.67±11.59	n=3	3.82±2.82	n=11	Not calculated
Hip flexion, max	27.50±11.90	n=26	25.62±6.80	n=26	0.487
Hip flexion, min	8.80±6.30	n=5	–	–	–
Hip extension	9.24±10.15	n=21	12.27±7.77	n=26	0.253
Knee flexion, max	54.77±12.88	n=26	60.85±3.65	n=26	0.025*
Knee flexion, min	9.55±4.50	n=19	7.95±3.89	n=21	0.141
Knee extension	3.57±3.73	n=7	2.40± 2.51	n=5	Not calculated
Ankle flexion, max	16.23±6.40	n=26	17.04±5.87	n=26	0.638
Ankle extension	10.12±4.10	n=26	10.15±1.93	n=26	0.953

SD – standard deviation, *– statistically significant, P – independent samples T test, to compare joint motions in the patients´ group and the control group, „–" no corresponding parameter in the control group and P value.

We found that polytrauma patients group in the uninjured lower extremity had a decreased knee maximum flexion in comparison with the control group (Fig. 2.1.).

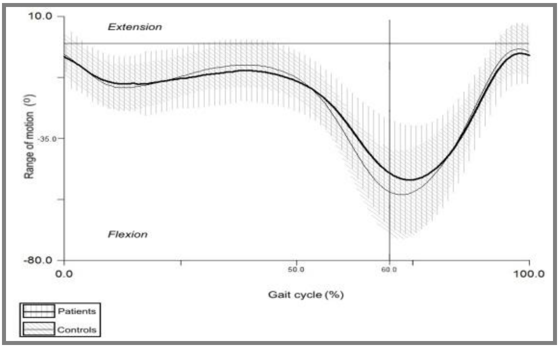

Fig. 2.1. Knee joint motions in sagittal plane in the uninjured lower extremity of polytrauma patients and of the healthy control group

Gait cycle motion parameters of pelvis, hip, knee and subtalar joint in the **frontal plane of uninjured side in patients with unilateral injuries** displayed in table 2.2.

Table 2.2.

Frontal plane motions in pelvis, hip, knee and subtalar joints in the uninjured lower extremity of polytrauma patients and of the healthy control group during gait cycle

Parameters	Polytrauma group (n=26)		Control group (n=26)		P
	Mean ±SD(°)	n	Mean±SD(°)	n	
Pelvis ↓ in stance	2.19 ±1.86	n=21	2.91 ±1.92	n=23	0.214
Pelvis ↓ in swing	2.14±1.23	n=14	2.27±1.48	n=22	0.780
Hip abduction	3.67±2.08	n=3	–	–	–
Hip adduction	9.35±5.66	n=23	9.42± 3.59	n=26	0.955
Knee abduction	5.80±3.25	n=20	5.33±2.70	n=21	0.620
Knee adduction	6.17 ±6.73	n=6	4.20±1.92	n=5	Not calculated
Subtalat inversion	4.21±3.34	n=24	6.54 ±4.64	n=24	0.052*
Subtalar eversion	6.27±3.98	n=26	6.08±3.70	n=26	0.859

SD – standard deviation, n– number of patients *– statistically significant, P – independent samples T test, to compare motions in the patients´ group and the control group, ↓ – decreasing, „–” no corresponding parameter in the control group and P value.

In the evaluation of GC motion parameters in pelvis and the mentioned joints in the frontal plane of the uninjured lower extremity of polytrauma patients and the control group, we found that there were significantly decreased inversion in the subtalar joint (Fig. 2.2.).

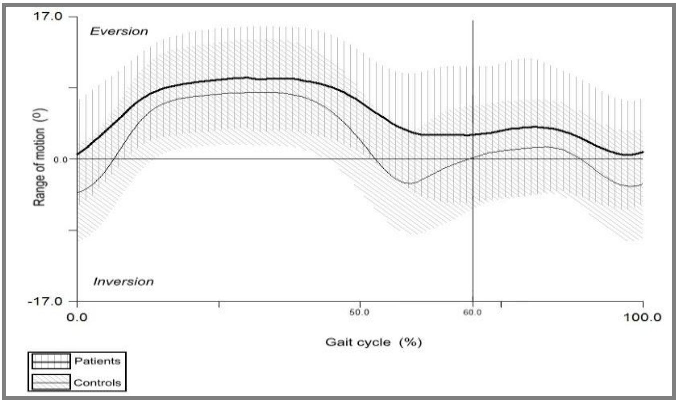

Fig. 2.2. Subtalar joint motions in frontal plane in the uninjured lower extremity of polytrauma patients and of the healthy control group

Table 2.3.

Ground reaction force in the uninjured lower extremity of polytrauma patients and of the healthy control group

Parameters	Polytrauma group (n=26)	Control group (n=26)	P
	Mean±SD (GRF/weight)	Mean±SD (GRF/weight)	
GRF A	0.14±0.05	0.18±0.03	0.005*
GRF P	0.11±0.03	0.14±0.03	0.000*
GRFV1	0.97±0.06	1.05±0.09	0.001*
GRF V2	1.02±0.19	1.13 ±0.08	0.014*

GRF A– maximal anterior ground reaction force in terminal stance, GRF P – maximal posterior ground reaction force in loading response, GRF V1– maximal vertical ground reaction force in loading response, GRF V2– maximal vertical ground reaction force in terminal stance, n– number of patients, SD – standard deviation, P – independent samples´ T test, to compare GRF in the patients group and control group, *– statistically significant.

Ground reaction force parameters anteriorly, posteriorly and vertically **in the uninjured side of polytrauma patients with unilateral injuries of lower extremities** and the control group displayed in table 2.3.

We found that in the uninjured lower extremity in the polytrauma patients group and the control group GRF is decreased anteriorly, posteriorly, as well as vertically (Fig. 2.3.).

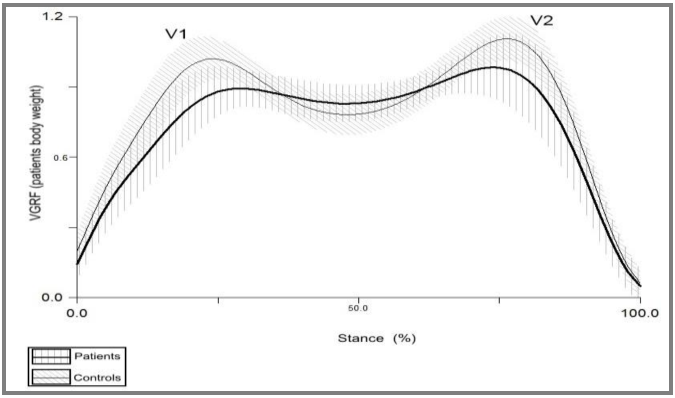

Fig. 2.3.Vertical load ground reaction force in the uninjured lower extremity of polytrauma patients and of the healthy control group

In this figure:VGRF – vertical ground reaction force, V1– maximal vertical ground reaction force in loading response, V2– maximal vertical ground reaction force in terminal stance.

2.3. Comparison of gait deviations and polytrauma severity

To evaluate if severity of polytrauma according to ISS and NISS is connected with functional outcome we compared mean ISS and NISS of subgroups of patients with moderate, serious and severe GD.

Out of 7 patients with moderate GD two patients had polytrauma with moderate injuries (NISS 17−25) and five patients had polytrauma with serious injuries (NISS 27−34). Out of 18 patients with serious GD nine patients had polytrauma with moderate injuries (NISS 17−26), seven patients had polytrauma with serious injuries (NISS 27−34) and two patients had polytrauma with severe injuries (NISS 41−48). Out of 8 patients with severe GD three patients had polytrauma with moderate injuries (NISS 22−26) and five patients had polytrauma with severe injuries (NISS 27−34). One patient with very severe GD had polytrauma with moderate injuries (NISS 22).

In the comparison of severity of GD and polytrauma severity we found that 9 patients had appropriate polytrauma severity and GD. In the 17 polytrauma patients group with moderate injuries thirtheen had more severe GD than the severity of polytrauma. In the 15 polytrauma patients group with serious injuries five had more severe GD than the severity of polytrauma. Patients who had polytrauma with moderate injuries but severe GD, had sciatic nerve palsy, deep peroneal nerve palsy or delayed union of fractures which caused medium-term GD. The comparison of GD and polytrauma severity is displayed in Fig. 2.4.

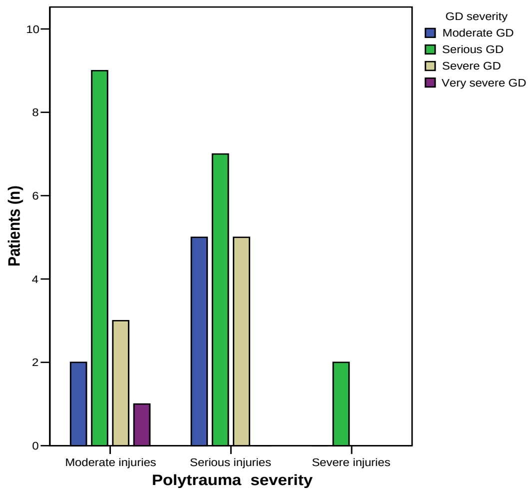

Fig.2.4. Comparison of gait deviations (GD) and polytrauma severity

Out of 21 patient who had articular fractures of lower extremities three patients had moderate GD, eleven patients had serious GD, six patients had severe GD and one patient had very severe GD. Out of 13 patients who had extraarticular fractures of lower extremities, four patients had moderate GD, seven patients had serious GD, two patients had severe GD. We compared GD severity with NISS. To find out if GD severity is dependant on NISS, we performed correlations analysis and determined Speermens correlation coefficient. This coefficient showed that there was no statistically significant correlation between NISS and GD (rs=0.926, P>0.05). To determine the ISS and NISS relations between subgroups of patients with different GD severity, we calculated P value, comparing ISS and NISS in the aforementioned patients´ subgroups. We found that in polytrauma patients with moderate injuries ISS and NISS does not differ (P>0.05), but in polytrauma patients subgroups with serious and severe injuries NISS was higher than ISS (P<0.05) (Table 2.4.).

Table 2.4.

Injury severity score and New injury severity score comparison with gait deviations severity in polytrauma patients with lower extremities injuries

Injury severity scales	Moderate GD (n=7)	Serious GD (n=18)	Severe GD (n=8)	Very severe GD (n=1)
	Mean±SD	Mean±SD	Mean±SD	Score
ISS	20.71±8,07	22.39±10,22	21.25±3,69	9
NISS	26.57±5,08	26.56±8,47	27.62±4,62	22
P	0.068	0.003*	0.018*	Not calculated

In this table: ISS – Injury severity score, NISS – New injury severity score, GD – gait deviations, n – number of patients, SD – standard deviation, *– statistically significant, P – Wilcoxon Signed Ranks test for comparison of two dependant groups, to compare the patients with different gait deviations severity, ISS and NISS.

3. DISCUSSION

3.1. Connection of study with literature data and limitations of the study

The investigation of functional outcomes in the polytrauma patients with consequences of orthopaedic injuries using self-report questionnaires can be used for large number of patients, but it is subjective. (12) Functional capacity index is described as AIS based sign of functional result after trauma, but it does not refer to the polytrauma. (13) The two largest and most respected long-term studies of polytrauma patient outcome using questionnaires and clinical examination: The Lower Extremity Assessment Project and The Hannover Rehab Study are described. (14) *Kubota et al,* 2012 analyzed spatio-temporal, kinematic and kinetic GC parameters 3 and 12 months after internal fixation of fractures of acetabulum. The authors found that these patients had decreased hip abductor strength in the injured side, therefore hip abductors should be trained early after operation. (15) There are no data about research of functional result after polytrauma of patients with musculoskeletal injuries in Latvia, using IGA.

In our study we evaluated functional result of patients with consequences of injuries of lower extremities after polytrauma, using clinical examination and IGA and analyzed data of both of the lower extremities − the injured or most injured and the uninjured or less injured one. Our data show that polytrauma patients with consequences of injuries of lower extremities in comparison with the control group had decresed cadence, increased stance time, decreased step length, increased pelvic anterior tilt, decreased maximal flexion in the knee joint and decreased anterior, posterior, vertical load GRF; besides in the injured or most injured side they have decreased hip extension, increased pelvic drop during the stance and swing, but decreased inversion in the subtalar joint in the uninjured or less injured side.

Analyzing the GC parameters in the patients subgroups with articular and extraarticular fractures, we found that in the patients subgroup with articular fractures there was increased minimal flexion in the knee joint in comparison with patients subgroup with extraarticular fractures.

We analyzed separately clinical examination and IGA data of the uninjured lower extremity of patients with unilateral lower extremities injuries. We compared GC data of the patients with the healthy control group. Using IGA, we analyzed the connection among ISS, NISS and GD.

The age range of the polytrauma patients and the healthy control group individuals was considered to be appropriate to compare gait changes in our study, because the studies point to GD in the elderly after 65 years of age. (16, 17)

We evaluated patients in 1−3 years after polytrauma. Most of the clinical recovery outcomes of severe lower extremity trauma are attained after one year, therefore one year after trauma was considered to be within the period when the gait does not change significantly in the future. (18) Besides a relatively short time after trauma gives a possibility to analyze pathology causes found in the clinical examination and by IGA as well as provide treatment.

We have some limitations in our study.

1. The polytrauma patients in our study had multiple injuries, including the injuries of pelvis and lower extremities, which possibly could interfere with the functional result. In our study there were no patients with equal diagnosis, therefore it was not possible to divide patients into the subgroups according to the anatomical location of the lower extremities fractures and dislocations to compare the functional result in the subgroups of patients according to the location of injuries. Nevertheless, we devided the patients into two groups according to the AO classification of the fractures regarding the injury of articular surface – patients subgroups with articular and extraarticular fractures

in the injured or most injured side, which, we think, is one of the important factors influencing the functional result. Injuries of other anatomical regions might interfere with the function of lower extremities.

2. Polytrauma patients were treated with different conservative and surgical methods, which could interfere with the functional result. Therefore because of the small number of patients it was not possible to divide patients into the subgroups and compare the results according to the methods of treatment.

3. Although the period of 1−3 years after trauma is not long, we chose this period because it is possible to correct the functional abnormalities, if they are found.

4. There were different relations between men and women in the polytrauma patients and the control group, but the literature data report that GC parameters do not significantly differ between them. (19, 20)

5. We did not compare the functional result of patients, who had rehabilitation after polytrauma and those, who had no rehabilitation because the number of patients in subgroups would have been too small to compare the results.

6. Social, psychological and economical factors were not analyzed in our study, which might influence the polytrauma patients´ functional result.

3.2. Fracture union complications of patients after polytrauma

Most of the patients (88 %) had no fracture union in the normal time of the consolidation of fractures. Fracture union delay is a frequent complication after polytrauma and is caused by many factors. Polytrauma is caused by high energy trauma. To compare with low energy trauma, polytrauma patients have a large bone injury, severe soft tissue injuries, severe haemorrhagic shock, hipoxia which is caused by lung injury and early complications, connected with these injuries causing circulation disturbances in the place of the fracture, which increase the risk of fracture union delay. In the place of high energy injury there are severe soft tissue injuries with blood supply disturbances which is the main cause of fracture union complications. As bone blood supply is mainly from soft tissue blood vessels, this is the main factor of normal fracture union. Polytrauma patients often have open fractures. Injuries of skin, muscles, major blood vessels, nerves and periosteum in the place of open fracture worsen the prognosis of fracture union. High energy caused fractures often are multifragmentary. After debridement of the wound and extirpation of dead tissue, there can be bone defects which cause fracture union disturbances. Fracture union is influenced also by associated injuries and tactics of bone fixation which is connected with life saving surgery priority. Using the monolateral external fixation as the definitive treatment method, there can be fracture union complications because of lack of fracture stability. (21) As high energy caused fractures are with severe displacement, periosteum is detached from a bone and there are disturbances of intramedullary blood supply. Complications of fracture union can be caused by infection. If fractures are non imobilized or poorly imobilized in the prehospital stage, there is an increased risk of displacement of bone fragments which causes additional injuries of soft tissue that increases the risk of development of fracture union complications. (22) Taking into account the aforementioned, it is possible to explain the fracture union complications in most of polytrauma patients.

3.3. Evaluation of the clinical orthopaedic examination in patients after polytrauma

The motion pathology in joints found in the clinical orthopaedic examination show that injuries of the extremities decreases ROM in the joints. Decreasing of ROM in the injured side of uninjured joints show that patients perform movements in these joints carefully. Range of motion is significantly decreased in the ankle joint in the patients with articular fractures of distal segment of tibia, as well as in patients with sciatic nerve and deep peroneal nerve palsy.

Decreasing of ROM in the uninjured side in patients with unilateral lower extremities injuries might be connected with muscle weekness which was diagnozed in most of the patients not only in the injured, but also in the uninjured lower extremity.

3.4. Specific features of the IGA data in the evaluation of functional result in patients after polytrauma

The evaluation of IGA data and comparison with the control group helps to diagnoze the motion abnormalities in polytrauma patients' lower extremities which often cannot be fully detected and evaluated by clinical examination methods only. Evaluation of IGA data of patients after polytrauma is a difficult task because the consequences of injuries interfere. We selected GC spatio-temporal, pelvic and lower extremities´ joints sagittal and frontal plane motions analysis because they are more responsible for pathological changes, severity of GD and reflect the connection between motions in joints and muscle strength. Time and distance parameters of GC were significantly changed in both sides. Most of the patients had increased pelvic anterior tilt in both sides which showed inability to extend the hip joints during the stance phase of the GC, or a shorter leg in the injured side. The patients who had increased pelvic posterior tilt had weakness of hip flexors. Increased knee minimum flexion during all GC was due to knee joint contracture of the injured lower extremity, but the increased knee minimum flexion during the swing was due to inadequate function of femoral posterior group muscles. Extension in the ankle joint did not differ from the control group, as two patients had flexion contracture because of sciatic nerve or deep peroneal nerve palsy. Patients with unilateral lower extremities injuries consequences in the uninjured lower extremity and the same extremity in the control group in the initial swing had differed decreasing of knee maximum flexion, that points to the weekness of hip flexors as well as the combined weekness of quadriceps muscle and ankle flexors. Evaluation of IGA allowed differentiations between motion abnormalities due to functional reasons (muscle weakness) and motion abnormalities due to permanent reasons (contracture, ankylosis). The GRF was significantly decreased in the injured and uninjured side anteriorly, posteriorly and vertically due to increased hip maximum flexion and decreased vertical loading force during loading response and terminal stance. Rehabilitation of polytrauma patients should be performed as early as possibly, in the plan of rehabilitation including development of strengh of abdominal muscles, hip abductors and extensors, quadriceps, hamstrings and ankle flexors, and especially the development of the strengh of hip extensors, quadriceps, hamstrings and ankle flexors in the uninjured side.

In the evaluation connection among ISS, NISS and severity of GD, we found that polytrauma patients who had NISS more than ISS had serious or severe GD. This difference might be explaned with multiple injuries of lower extremities which cause functional limitations during GC. We advise these patients to undergo IGA to find out these limitations. Patients with complex foot injuries, articular fractures, major nerve damage and complete ligament injuries to the lower extremities can have severe medium-term impaired function in the lower extremities regardless of low ISS and NISS score, therefore we advise to perform IGA also to these patients, to evaluate GD severity and provide necessary treatment to improve their functional result.

3.5. Implementation of study results in the evaluation of polytrauma patients in the early and medium-term after polytrauma

On the basis of our study results, we advice the following:

1. in the prehospital stage evaluate the multiply injured patients according to the primary survey (ABCDE) algorithm and provide appropriate emergency care according to this algorithm;

2. in the hospital emergency department evaluate the multiply injured patients according to the primary survey algorithm, provide immediate life saving procedures and perform secondary survey after stabilization of vital signs;

3. in the hospital after statement of diagnosis calculate ISS un NISS;

4. in multiply injured patients with musculoskeletal injuries in the polytrauma severity determination use NISS;

5. planning the treatment of polytrauma patients with injuries of lower extremities, use the algorithm of the functional outcome prognosis of polytrauma patients with musculoskeletal injuries, thus decreasing the risk of severity of functional limitations (Fig. 3.1.);

6. introduce AIS, ISS and NISS in Latvia that would give a possibility to evaluate the severity of polytrauma and choose appropriate treatment based on damage control principles;

7. identify early the functional limitations of musculoskeletal system using clinical orthopaedic examination of polytrauma patients and follow-up;

8. identify the functional limitations of musculoskeletal system in patients after polytrauma using IGA.

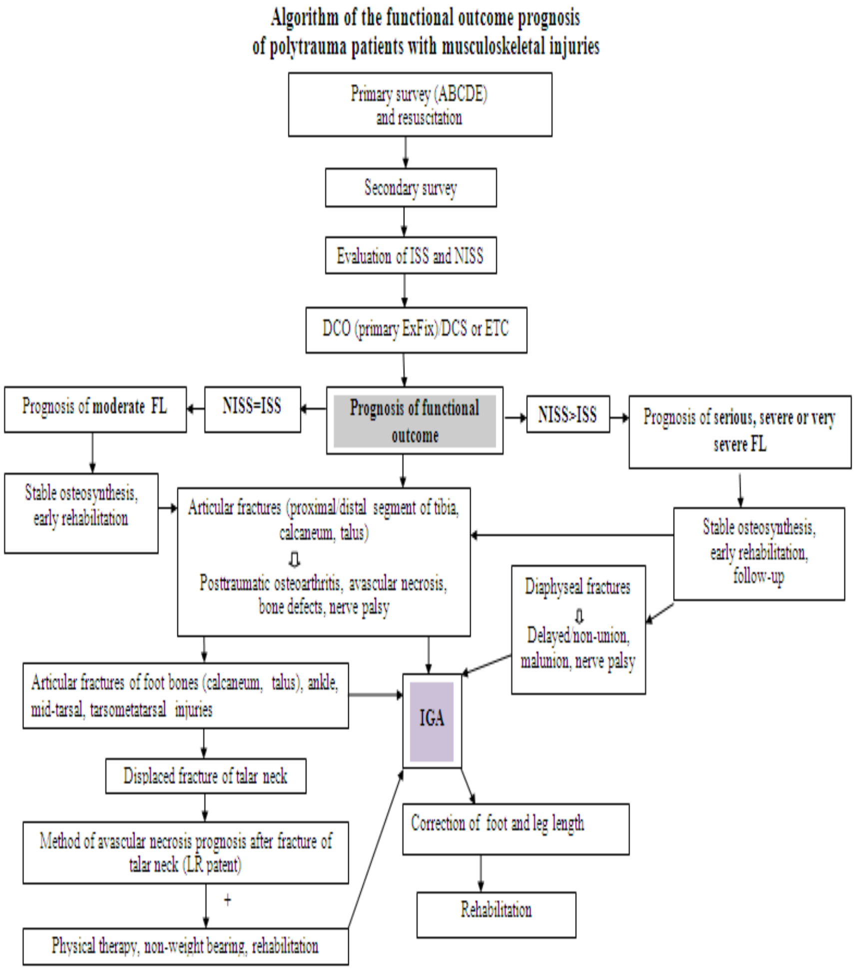

Fig. 3.1. Algorithm of the functional outcome prognosis of polytrauma patients with musculoskeletal injuries

ISS – Injury severity score, NISS – New injury severity score, DCO – Damage control orthopaedics, DCS – Damage control surgery, ETC – early total care (definitive fracture stabilization), FL – functional limitation, IGA – 3-dimension instrumental gait analysis.

*NISS less than ISS is not possible, because NISS is the sum of the squares of the three highest AIS scores anywhere in the body. If a patient has one lower extremities injury, NISS is equal the ISS, if there are several lower extremities injuries, NISS is more than ISS.

4. CONCLUSIONS

1. In patients after polytrauma using IGA it is possible to obtain data about functional limitations during GC which often cannot be fully detected and evaluated by clinical examination methods only.
2. In the study we found, that in patients with consequences of lower extremities injuries in the medium-term after polytrauma, in comparison with the control group was changed:
   2.1. in the injured or more injured side: GC spatio-temporal parameters; from GC motion parameters in the sagittal plane increased pelvic anterior tilt, decreased hip extension and knee maximum flexion, in the frontal plane incresed pelvic dro in stance and swing; decreased GRF;
   2.2. in the uninjured or less injured side: GC spatio-temporal parameters; from GC motion parameters in the sagittal plane is increased pelvic anterior tilt, decreased knee maximum flexion and increased knee minimum flexion, in the frontal plane decreased inversion in the subtalar joint; decreased GRF;
3. Patients with articular fractures had increased knee minimum flexion in comparison with patients, who had extraarticular fractures in the injured or more injured side.
4. In patients with consequences of unilateral lower extremities injuries in IGA we found functional limitations during GC also in the uninjured side: changed GC spatio-temporal parameters; from GC motion parameters in the sagittal plane decreased knee maximum flexion, in the frontal plane decresed inversion in the subtalar joint; decreased GRF. These findings are attributed to the secondary (compensatory) functional limitations in the uninjured side.

5. Instrumental gait analysis gives a possibility to differ in the injured extremity primary limitations of function from secondary functional limitions in patients after polytrauma and identify causes of compensatory functional limitations of uninjured lower extremity.
6. Using of IGA in the examination of polytrauma patients gives a possibility to plan and perform rahabilitation measures, taking into account the diagnozed functional limitations of lower extremities during GC.
7. Using ISS and NISS in polytrauma patients, it is possible to prognoze development of functional limitations. Therefore in patients who have incresed risk of functional limitations using ISS and NISS comparison, we advise detalized examination of injured lower extremities and appropriate treatment after stabilization of patients´ vital functions, taking into account the mechanism and the severity of the injuries (according to DCO principles).
8. Gait deviations severity in polytrauma patients does not correlate with NISS but is connected with severe associated injuries of lower extremities which cause late complications and functional limitations of lower extremities.

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Publications about study theme

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