

Preliminary data on the neurophysiological evaluation of male sexual dysfunction in patients with pelvic ring fractures: a multicenter retrospective study

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Abstract. – OBJECTIVE: Traumatic pelvic ring fractures include several comorbidities due to the close anatomical relationship between the skeletal system, pelvic organs, and neurovascular structures. In this retrospective multicenter study, we evaluated patients complaining of sexual dysfunction following pelvic ring fractures, assessed through different neuro-physiological examinations.

PATIENTS AND METHODS: Patients were enrolled one year after the injury according to their reported ASEX scores and evaluated on the basis of the Tile's type of pelvic fracture. Lower limb and sacral somatosensory evoked potentials, pelvic floor electromyography, bulbocavernosus reflex and pelvic floor motor evoked potentials were recorded, according to the neurophysiological indications.

RESULTS: A total of 14 male patients (mean age 50.4; 8 subjects Tile-type B and 6 Tile-type C) were enrolled. The ages between the Tile B group and the Tile C group of patients were not significantly different ($p=0.187$), while the ASEX scores were significantly different ($p=0.014$). In 57% of patients ($n=8$), no alterations in nerve conduction and/or pelvic floor neuromuscular responses were found. In 6 patients, electromyographic signs of denervation were revealed (2 patients), and alterations of the sacral efferent nerve component were detected in 4 patients.

CONCLUSIONS: Sexual dysfunctions after a traumatic pelvic ring fracture are more common

in Tile-type B. Our preliminary data did not reveal a significant association with neurogenic aetiology. Other causes could explain the complaining impairments.

Key Words:

Pelvic ring fracture, Penile erection, Sexual dysfunction, Neurophysiologic assessment, Electromyography, Rehabilitation.

Introduction

Traumatic Pelvic Ring Fractures (TPRFs) are uncommon injuries that account for only 2-8% of all fractures¹. They could be due to high-energy or low-energy trauma. High-Energy Pelvic Ring Fractures (HE-PRF) are more common in the young population, frequently occurring in road traffic accidents or accidents at work. In turn, Low-Energy Pelvic Ring Fractures (LE-PRF) are more common in the elderly (over 80 years) as a result of metabolic or metastatic bone diseases². In patients with severe polytrauma, TPRF are observed in 20-25% of the patients and are associated with significant mortality and morbidity due to hemodynamic instability³.

Independently by the type of trauma, multidisciplinary care is required. Many patients suffer multiple injuries, including major bleeding, often resulting in a delayed diagnosis. The close anatomical relationship between the skeletal system and the pelvic organs may contribute to functional and structural impairments (especially gastrointestinal, genitourinary, and gynecological)⁴⁻⁶.

Sexual dysfunction (SD) is a common comorbidity of the TPRF, caused by direct or indirect trauma to the neurovascular structures within the pelvic cavity^{6,7}. These deficits are underestimated even in young patients, resulting in depression and a diminished quality of life^{5,8,9}. Injury may affect the nerve structure of the pudendal plexus (S2-S4), either partially (axonotmesis) or entirely (neurotmesis)¹⁰. Neurophysiological evaluation is critical to verifying the neurological origin of the etiology of the disease, but they are difficult to perform and require full cooperation from the patient.

Several scholars⁵ have examined the sexual function of patients following pelvic fracture surgery. Most of these studies are generally based on patient-reported outcomes. Although they may be useful in evaluating functional outcome of pelvic fractures studies, they could be insensitive to detect sexual and urological diseases and their effects on patients' lives. Very few studies⁴⁻⁹ have examined neurophysiological dysfunctions in assessing sexual disorders after traumatic pelvic ring fractures. In this study, we have retrospectively evaluated patients complaining of sexual dysfunction following pelvic ring fractures, assessing them with different neurophysiological examinations.

Patients and Methods

Patients and Outcomes Measures

We have conducted an observational retrospective multicenter study, approved by the board of the Osteosynthesis and Trauma Care Association in Italy. Patients admitted to the Departments of Orthopedics and Traumatology and underwent surgery between January 2020 and June 2021 were retrospectively evaluated for sexual dysfunction. These subjects were enrolled in the study based on the following inclusion criteria: age between 18 and 65 years old, presence of traumatic pelvic ring fractures caused by high energy trauma (one or more),

follow-up clinical assessment at one year after the injury, presence of sexual impairment as determined by the Arizona Sexual Experiences Scale (ASEX), consent to perform the neurophysiological examinations.

The ASEX is a reliable self-report scale that assesses different aspects of sexual function, including sex drive, arousal, vaginal lubrication/penile erection, the ability to reach orgasm, and the satisfaction experienced during orgasm. The possible total scores range from 5 to 30, with the higher scores indicating more sexual dysfunction¹¹. Patients were considered to have an impairment in sexual functioning if they achieve a total ASEX score of 19 or if they scored 5 on any item or scored 4 on any three items. Different studies¹²⁻¹⁴ have demonstrated the utility of using the ASEX questionnaire in individuals with different neurological diseases. This scale has been recently validated in Italian¹⁵.

Radiographs and computed tomography (CT) images were used for injury pattern and classification according to the modified Tile's classification for pelvic fractures¹⁶, to analyze surgical outcomes and the residual displacement during follow-up. The Tile's classification takes into account the integrity of the posterior arch. These patients were classified as type A (stable, minimally displaced), type B (rotationally unstable, incomplete disruption of the posterior arch, vertically stable), and type C (rotationally and vertically unstable, complete disruption of the posterior arch).

We also classified the trauma with the Injury Severity Score (ISS), an anatomical scoring system providing an overall score for patients with multiple injuries¹⁷. Major trauma is defined for ISS>15. This system has been found to correlate with several important trauma outcomes such as mortality, morbidity, and duration of hospitalization¹⁸.

Finally, we also described the TPRF according to more recent AOSpine Sacral Classification System¹⁹. This classification divides into 3 main sacral fractures on the basis of their morphological criteria: type-A (lower sacrococcygeal) fractures; type-B (posterior pelvic) fractures; and type-C (spinopelvic) fractures, each type further subdivided into 3 or 4 subtypes for the severity grade.

Patients with previous urogenital or sexual pathology or former orthopedic pelvic ring surgery, concomitant oncological or hematological diseases, or overt urogenital pathology, were excluded.

This study was conducted after the approval of the Institutional Review Board of all the departments. All subjects gave written informed consent before participation.

Neurophysiological Assessment

All patients were evaluated by an experienced neurologist in every center involved in this multicenter study. The following examinations were conducted.

Lower Limb Somatosensory Evoked Potentials

This diagnostic technique allows the evaluation of the tibial nerve's somatosensory pathway through the posterior medullary cord, lemniscal trunk-encephalic and thalamic pathways. The recording electrode is located at the level of the dorsal-lumbar spinous processes and the deriving electrode is positioned 2 cm posterior to Cz, calculated through the 10-20 system²⁰. The patient is in the supine position. An external bipolar stimulator is positioned on the internal malleolus, with the following attributes: duration of 0.2 ms, intensity until the foot is dorsiflexing, and frequency of 1 stimulus per second. The response latency of the sensory pathway has physiological latency values $P40 < 43.5$ ms.

Sacral Somatosensory Evoked Potentials (SSEP)

This technique evaluates the somatosensory pathways originating from the pudendal nerve, similar to the procedure described above. In the male gender, the surface electrodes are connected with a cathode at the base of the penis and the anode 3 cm distal to the cathode, along the course of the dorsal nerve of the penis. In females, stimulation occurs with surface electrodes positioned on the clitoris. An overt stimulation occurs between 0.2 and 0.4 ms with a frequency of 1 stimulus per second and a stimulus intensity of 3-4 times the sensitivity threshold of 18-25 milliamps (with patient discomfort). Latency values are directly proportional to the patient's height and are considered physiological for P40 between 44.75-48.75 m/sec in males and 44.75-47.8 m/sec in females²¹.

Pelvic Floor Electromyography

The electromyography (EMG) procedure aims to detect neuromuscular abnormalities by measuring muscle response or electrical activity in response to nerve stimulation. The pelvic floor electromyography (PF-EMG) evaluates the in-

tegrity of the nerves that control the sphincter and genital function²². The test was carried out through the insertion of a small 37 mm disposable concentric needle electrode in the bulbo-cavernosus muscle in males and in the external sphincter muscle of the anus in females. After the electrode was inserted, patients were instructed to contract the muscle (e.g., by lifting or bending their leg). The action potential (the size and shape of the wave) displayed on the oscilloscope provides information about the ability of the muscle to respond when the nerves are stimulated²¹.

Bulbocavernosus Reflex

The Bulbocavernosus Reflex (BCR) measures the excitability and functional integrity of the reflex arc consisting of the afferents of the pudendal nerve (dorsal nerve of the penis and clitoris), perineal efferent fibers and sacral neurons at S2-S4 level. It was measured after PF-EMG by stimulating the dorsal nerve of the penis or clitoris at the base of the penis and in the paracloitoral area and by recording the response from the BC muscle. It was elicited by single-pulse electrical stimulation at 1.5 Hz frequency. The electrical stimulus was gradually increased until the patient's sensory threshold was reached. The intensity was increased to threefold the patient's sensory threshold. The BCR reflex shows a primary stable latency < 45 ms and a later latency duration between 50 and 75 ms^{23,24}.

Pelvic Floor Motor Evoked Potentials

The purpose of this investigation is to evaluate the excitability and functional integrity of the intracortical neuronal structures, the conduction within the subcortical efferent fibers, and the motor responses of the bulbocavernosus muscle or the external anal sphincter muscle²⁵. It selectively activates regions of the motor cortex through the generation of a magnetic field using a circular coil in which an electric current move. The motor area controlling the muscles innervated by S2-S4 is stimulated.

Statistical Analysis

Statistical analysis was performed using Stata software (StataCorp. 2017; Stata Statistical Software: Release 15.1, StataCorp LP, College Station, TX, USA). Descriptive statistics were conducted to describe the results of the neurophysiological assessment as absolute number and percentage per group. The *t*-tests analyses were performed to

assess the differences between the Tile B and the Tile C group for age and ASEX Score; a p -value <0.05 was considered statistically significant.

Results

The flow chart of the study is represented in Figure 1. Only 14 of 70 patients undergoing surgery for pelvic ring fractures, agreed to undergo

neurophysiological examinations. All individuals had HE-PRF, mostly due to accidents with vehicles. In Tables I and II are summarized the features of the enrolled patients, according to the Tile classification.

Despite not being a specific inclusion criterion, all enrolled patients were male. Only one female participant who had consented to perform neurophysiological examinations prematurely interrupted the diagnostic procedure. According to

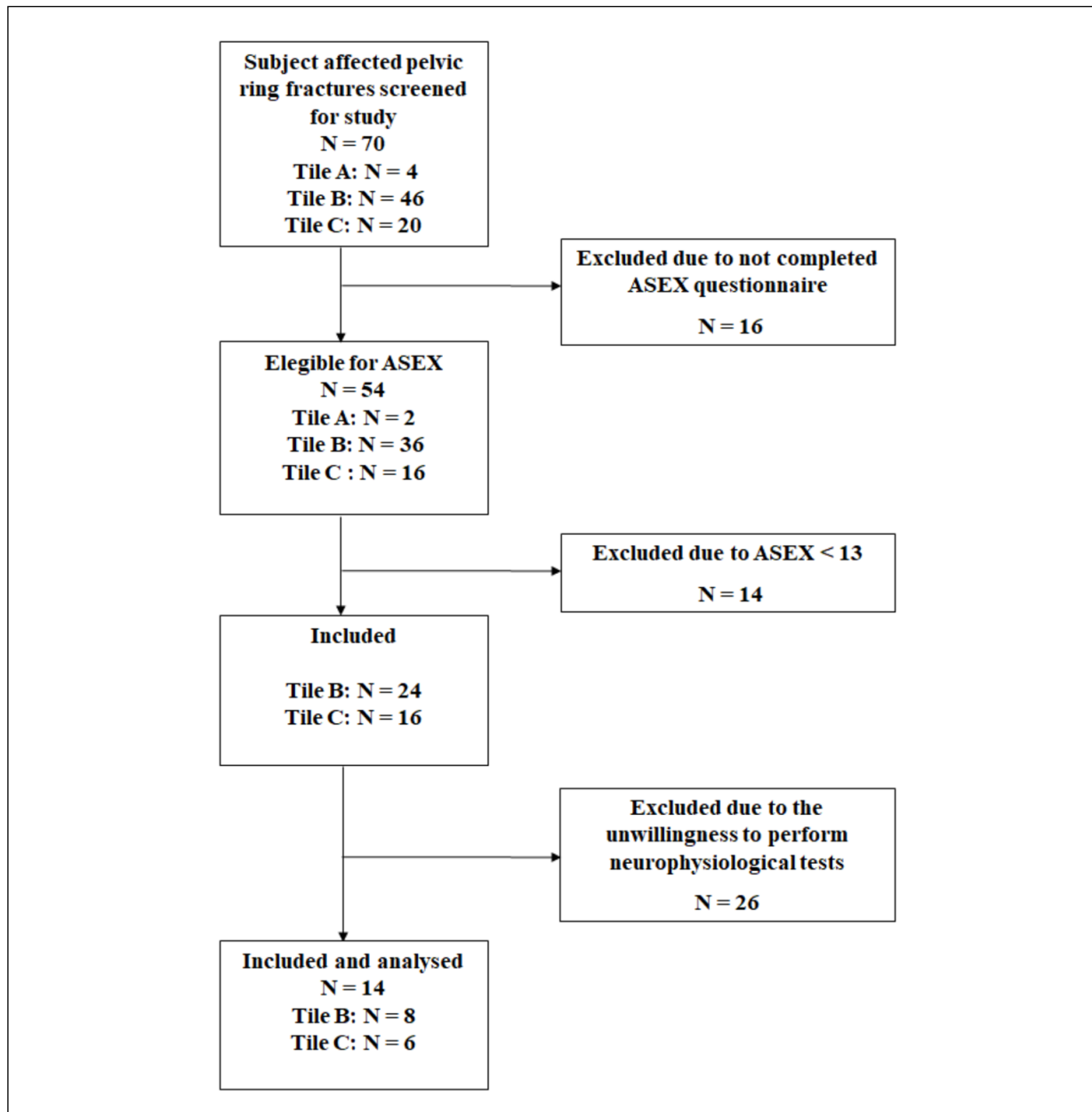


Figure 1. CONSORT study flow diagram for patients enrolled in the three orthopedic trauma centers with sexual dysfunction after traumatic pelvic ring fractures according to Tile Classification. ASEX: Arizona Sexual Experiences Scale.

Table I. Clinical and demographic features of the enrolled patients according to the Tile B classification.

	Age	Sex	Type of trauma	Tile classification	ASEX at 12 months	ISS	AOSSC
1	52	M	Motorcycle accident	B1	19	13	-
2	58	M	Car accident	B1	20	12	A1
3	42	M	Motorcycle accident	B1	17	13	A1
4	55	M	Car accident	B2	15	15	B2
5	56	M	Invested by car	B1	17	12	-
6	61	M	Motorcycle accident	B1	18	11	-
7	44	M	Fall from Height	B1	19	10	-
8	35	M	Car accident	B2	16	17	B3

B1: external rotation due to open-book fracture; B2 is internal rotation due to lateral-compression injury. ASEX: Arizona Sexual Experiences Scale; ISS: Injury Severity Score; AOSSC: AOSpine Sacral Classification.

Table II. Clinical and demographic features of the enrolled patients according to the Tile C classification.

	Age	Sex	Type of trauma	Tile classification	ASEX at 12 months	ISS	AOSSC
1	54	M	Motorcycle accident	C1	14	17	B2
2	41	M	Car accident	C1	15	23	B3
3	47	M	Car accident	C2	17	24	C0
4	56	M	Car accident	C2	13	25	C1
5	19	M	Invested by car	C3	14	27	C2
6	34	M	Fall from height	C3	17	24	C2

C1: iliac, sacroiliac and/or sacral fracture; C2: bilateral with one side type B and one side type C; C3: bilateral, both sides with type. ASEX: Arizona Sexual Experiences Scale; ISS: Injury Severity Score; AOSSC: AOSpine Sacral Classification.

the Tile B classification, we enrolled 8 patients who completed the protocol (mean age 50.4±9.1 years old); 6 subjects were diagnosed with TPRF tile type B1 and 2 with TPRF tile type B2. At the moment of the neurophysiological evaluation (around one year after the injury), the mean ASEX score of these patients resulted 17.1 (±1.7). All patients underwent surgical intervention type open reduction internal fixation (ORIF).

Similarly, 6 patients were enrolled according to Tile-type C classification (mean age 41.8±13.8 years old; 2 patients with Tile-type C1, 2 with Tile-type C2, 2 with Tile-type C3). One patient underwent transarterial embolization (TAE), reporting signs of denervation at the neurophysiological assessment. The mean ASEX score of

these subjects was 15 (±1.7). In this group, two patients underwent a surgical intervention with closed reduction internal fixation (CRIF) prior to ORIF, whereas the remaining six patients underwent ORIF directly.

The ages between the Tile B group and the Tile C group of patients were not significantly different (*t*-test: *p*=0.187), while the ASEX scores were significantly different (*t*-test: *p*=0.014).

Table III reports the results of the neurophysiological assessments of the whole sample. No alterations in nerve conduction or pelvic floor neuromuscular responses were found in 8 patients (57%; 4 patients with Tile-type B and 4 with type C). Among the six patients who were positive at neurophysiological examination, PF-

Table III. Results of the neurophysiological assessment.

Type of fracture (tile)	No neurophysiological alterations	Sensitive pathway alteration	Motor pathway alteration (EMG, BCR and/or MEP)	Both sensitive and motor alteration
B	4	0	2	2
C	4	0	2	0

EMG revealed signs of denervation in 2 patients (14%) with type-C fractures, while 4 patients (29%) with type-B tile fractures were found to have alterations in the sacral efferent nerve component. In 2 of these 4 patients, electromyographic signs of neurogenic damage with sub-interferential activity at maximal contraction and SSEP across the pudendal nerve of reduced amplitude compared to normal were found. In the other two patients, a BCR with reduced amplitude and latency in the normal range was observed. An electromyographic evaluation recording of the motor evoked potential in the bulbocavernosus muscle of all four subjects showed a low amplitude.

Discussion

In this study, neurophysiological assessments were performed on patients suffering from sexual dysfunction following pelvic fractures. Our preliminary results suggest that sexual deficits are not strictly related to altered nerve root pathways, as less than half of the sample (6 out of 14 examined individuals) displayed neurophysiological abnormalities (motor or sensory conduction). The motor pathway demonstrated signs of myelin damage, as there were significant conduction deficits associated with an altered latency and normal amplitude. Only two patients with SD had abnormal electromyography of the pudendal nerve.

Around the half of patients who could be enrolled refused to perform the neurophysiological examination (Figure 1). Interestingly, no females were enrolled in the study, due to their decision not to conduct any neurophysiological testing. The only female who accepted to execute the exams interrupted immediately the procedure due to the discomfort derived by the procedure. Performing and interpreting the neurophysiologic assessment of pelvic nerve structures requires highly trained personnel and high compliance of the patients, as they are moderately invasive²⁶. As a result, the genitourinary lesions that caused the SD are not evaluated in many patients.

The mean age of the whole sample was 46.7 years old. In a previous study²⁷, it has been shown as individuals between 50 and 59 years of age are most likely to suffer from SD. Associated factors such as age, comorbidities, and psychological features as well as the type of intervention could impact in developing SD and influencing the overall outcomes in pelvic fractures and other different

musculoskeletal disorders²⁸⁻³². This could also explain the positivity of neurophysiological assessment in less than half of our sample.

The neurogenic etiology of SD does not appear to be the only contributing factor in our study. Interestingly, more patients with Tile-type B fractures had neurophysiological abnormalities (4 subjects). Consistently, these individuals achieved significantly higher scores at ASEX evaluation than patients with Tile-type C pelvic ring fractures (2 subjects). We suppose that genitourinary dysfunctions may be more frequent in Tile-type B due to the trauma mechanism. Tile-type B1 fractures are the results of anterior to posterior compression, leading to a direct injury by compression. In these patients, we obtained higher scores at ASEX (minimum/maximum: 17-20). It is interesting to note that 4 out of 6 patients did not suffer sacral fractures, as revealed by AOSSC. Tile-type B2 and B3 fractures are often derived from lateral compression. As a result, SD may be caused both by direct trauma to the genitourinary organs and by indirect trauma to neurovascular structures. In our sample, we found only two patients suffering from Tile-type B2 fractures, with ASEX scores of 15 and 16. Tile-type C fractures occur as a result of vertical or multidirectional trauma. In this case, the force vectors may pass through the head of the femur and sacrum without affecting the pelvic organs. There could not have been a direct impact on neurovascular structures, resulting in lower scores on the ASEX evaluation. In spite of this, more studies are required in order to confirm this hypothesis due to the small sample size; also, other causative factors should be considered.

No other study has revealed neurophysiological alterations based on the type of TPRF. Reilly et al³³ found that 21% of individuals were diagnosed with nerve injuries at the time of preoperative evaluation. Approximately 2/3 of the cases were related to motor and sensory deficits, and 1/3 of these subjects suffered sensory deficits alone. In a post-mortem study³⁴ of patients with unstable pelvic ring fractures, authors showed that most nerve injuries are located in the lumbosacral trunk and the superior gluteal nerve. Guan et al¹⁰ investigated the neurogenic cause of DS in patients with erectile dysfunction following pelvic trauma through SSEP and BCR. Alterations were found in 59% of the patients.

It is currently known that the causes of SD can have either neurogenic or vascular aetiology,

but few studies^{35,36} have attempted to distinguish between the two causes. Erection is the most frequent SD and depends on a combination of psychosomatic stimuli. The preponderant system that regulates erection is the parasympathetic system *via* autonomic fibers carried by the pudendal nerve (S2-S4), which can bring about reflex penile erection (physical stimulation)³⁷. The sympathetic nervous system (T12-L3) innervates the structures of the external genitalia *via* the hypogastric nerve and appears to be involved in psychogenic penile erection. This aspect seems to explain the mechanism underlying lower motor neuron syndrome³⁷. Patients with lower motor neuron syndrome have no reflex erection following tactile stimulation. However, psychogenic stimulation, mediated by the orthosympathetic system, may still be preserved³⁷.

Due to the small sample size, the absence of a control group, the high degree of variability among patients in terms of TPRF, and the limits of the genitourinary neurophysiological assessment, our results should be interpreted with caution and considered as preliminary. Further and wider studies are needed. The study was conducted in multiple centers over a period of 18 months to increase enrollment samples. Despite screening 70 patients with complaints of sexual dysfunction, most of them were excluded due to their unwillingness to complete the neurophysiological examination (26 individuals) or the ASEX questionnaire (16 individuals). In 14 subjects, the ASEX scores did not reveal a significant SD. Only 14 individuals were enrolled, and all the patients were male. This could probably be due to the neurophysiological assessments, as demonstrated by the high number of individuals refusing to be part of our study and by the examination's interruption of the only enrolled female.

Another limit could be considered the short term of follow-up (1 year). It has been noted as an excessive time of evaluation in the follow-up period (as 5-10 years or more) may determine a confounding factor to understand the correlation of SD as a result of injury^{38,39}. At the same time, we may consider a longer period in the follow-up time, also to determine a higher sensitivity of the neurophysiological examinations. Our data show as the diagnosis of SD is limited. We used the Arizona Sexual Experiences Scale to evaluate any sexual activity in the last week, in accordance with other studies^{40,41}. This could result in a variation in the results over time. We

have preferred to use a unique scale for both genders. To obtain more robust data, evaluating SD at different times may be necessary in future studies. Defining SD could also be difficult due to the poor compliance of patients to manage this impairment, both because of personal reasons to accept this impairment and due to age, as the elderly are less likely to be aware of these disorders. It has to be noted that other causes (vascular, psychogenic, etc.) could be at the basis of SD. Then, lower limb somatosensory evoked potentials could have low reliability in the evaluation of the sexual function including many artefacts and this could be great variability between different examiners, even if all patients were evaluated by experienced neurologists in this field. We did not report repeatability test values because of the retrospective design of this research. Further studies are necessary to validate the performance of this diagnostic procedure among different operators in the research settings.

In accordance with our aim, we did not perform an accurate evaluation of the urological and psychological conditions of the enrolled patients. It has been noted that patients who have sustained TPRF may be at increased risk for negative psychosocial disorders such as post-traumatic stress disorder and depression⁴²⁻⁴⁴. Considering the low number of alterations to neurophysiological assessments in our sample, it is possible that our sample could suffer from psychological distress.

As well, we did not investigate these possible etiologies as well as the possible role of the chronic medical conditions (pain, diabetes, hypertension, heart disease, prostatic hyperplasia) and the type of the used medications. Finally, possible causes of pre-trauma SD were not elucidated in this study because of the retrospective design.

A more sensitive diagnosis of SD could be achieved in future studies, also by integrating the information related to the anamnestic history of SD and the presence of comorbidities with other instrumental assessments (magnetic resonance, ultrasound) and the neurophysiological examinations. The development of multidisciplinary and specialized centers containing integrated professionals may help a complete individual treatment of the different comorbidities associated with TRPF. The use of registries dedicated to the routine diagnosis and treatment of SD in patients with traumatic pelvic ring fractures will permit to validate the data and diagnostic and therapeutic algorithms in future studies.

Conclusions

In conclusion, we have found that in operatively treated pelvic ring fractures, neurophysiological examinations are able to identify the neurogenic etiology of sexual dysfunction in around half of the patients after one year from the injury. In particular, SD appears more common in TPRF Tile-type B. This is the first study to quantitatively assess sexual dysfunction after pelvic fractures by means of neurophysiological assessment on the basis of the Tile classification. The results of our preliminary data did not indicate a significant association between neurogenic etiology and sexual dysfunction after TPRF. The complaining impairments could also be explained by other causes. Further studies are required to confirm our findings and explore other possible causative factors. A focus on sexual impairments is necessary during long-term follow-up visits of individuals after TPRF.

Conflict of Interest

All authors have disclosed potential conflict of interests related to the publication of this manuscript. The authors also declare no competing interests.

Authors' Contribution

Conceptualization: G.R., A.F. and A.S.; methodology: D.D.M, R.D.V, L.P. and L.M.; formal analysis: A.F. and R.E.; investigation: G.R., M.P., G.N., G.M. and G. Maccauro.; data curation: F.L. and G.R.; writing-original draft preparation: G.R. and A.F.; writing-review and editing: G.R.; visualization: A.F. and F.L.; supervision: F.L. All authors have read and agreed to the published version of the manuscript.

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Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

All procedures performed in the current study were in accordance with the 1964 Helsinki declaration and its later amendments. As this is an observational retrospective study, no ethical approval was required.

Informed Consent

Written informed consent was obtained from all individual participants included in the study. All consents for publication have been collected. All the patients gave written consent for their personal or clinical details along with any identifying images to be published in this study.

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