Annals of Medicine and Surgery 69 (2021) 102662

Contents lists available at ScienceDirect

Annals of Medicine and Surgery

journal homepage: www.elsevier.com/locate/amsu

Case Series

Ski- and snowboard related open peroneal nerve injury: A 20-year retrospective case series study

J. Metzler [a,1,*], E.M. Morandi [b], K. Schwaiger [a], D. Wolfram [b], T. Cakl [b], G. Djedovic [b], T. Bauer [b], G. Pierer [b], G. Wechselberger [a], C. Tasch [b,1]

[a] Department of Plastic, Reconstructive and Aesthetic Surgery, Hospital of St. John of God (Barmherzige Brüder) Salzburg, Paracelsus Medical University, Salzburg, Austria

[b] Department of Plastic, Reconstructive and Aesthetic Surgery, Medical University of Innsbruck, Innsbruck, Austria

ARTICLE INFO

Keywords:
Ski
Reconstructive surgery
Traumatic
Peroneal nerve injury
Case series

ABSTRACT

Introduction: Traumatic peroneal nerve injury (PNI) caused by ski or snowboard edges is a severe but scarcely reported accident.

Methods: In a 20-year retrospective study, all skiers and snowboarders with this injury treated surgically at the Department of Plastic, Reconstructive and Aesthetic Surgery at the Medical University of Innsbruck, Austria, were included, covering a period from 1999/2000 to 2018/2019.

Results: In total, 34 patients were included in this study (30 males (88.2%) and 4 (11.8%) females). Of these 34 injured skiers or snowboarders, 33 (97.1%) were recreational athletes and Non-Austrian citizens, and 21 (61.8%) patients sustained accidental injuries without collision. All of the injuries under investigation, i.e., open lacerations, most often with complete transection, were the patients' main injuries. Surgery was performed with direct coaptation in 24 patients (70.6%), and with a suralis nerve graft in the other 10 patients (29.4%).

Conclusion: Traumatic laceration of the peroneal nerve at the knee level by sharp ski or snowboard edges is a rare but severe injury. Causes for this injury may be multifactorial. Recommendations to reduce the risk of such an injury may follow general instructions and warnings to skiers and snowboarders regarding equipment, familiarity with the region, as well as appropriate skills and training.

Author statement

Conceptualization: Metzler, Tasch, Cakl, Methodology: Metzler Tasch, Cakl, Validation: Morandi, Schwaiger, Wolfram, Bauer, Djedovic, Data curation: Metzler, Tasch, Morandi, Formal analysis: Wechselberger, Schw, aiger, Pierer, Bauer, Djedovic, Writing: Metzler, Tasch, Project administration & Supervision: Wechselberger, Schwaiger, Pierer

1. Introduction

Skiing and snowboarding still represent the most attractive winter sport activities in Alpine regions and are popular in many areas all over the world. With 44% of all skier visits, the Alps are the largest ski area across the world, followed by North America [1]. Austria welcomes the most foreign skiers, 66% of the total skiers in Austria are foreigners [1] of any country around the world and benefits from a global increase in international tourism.

As an attractive winter sport activity, however, this sport carries the risk of ski- and snowboard-related injuries. In Austria, approximately 25.000 skiers and 5000 snowboarders are injured annually [2]. In Germany, approximately 43.000 skiers were injured during the 2017/2018 season [3]. One of the most recent comprehensive studies reviewed the published literature from 1985 to 2018, indicating a total of 64.667 Alpine skiing injuries [4]. Most statistics such as these, when analyzing the injury site, describe the typical, most frequent regions such as the knees, head and shoulders. By focusing on these regions, more specific injuries of a relatively low incidence, but nevertheless of significant relevance and severity, may be rather neglected.

After the first report of injuries to the nervous system and spine during downhill skiing by Myles et al., in 1992, Wechselberger et al.

* Corresponding author.Department of Plastic, Reconstructive and Aesthetic Surgery Hospital of the Brothers of St. John of God (Barmherzige Brüder) Paracelsus Medical University Salzburg, Austria Kajetanerplatz 1, 5020, Salzburg, Austria.

E-mail addresses: Julia.metzler@gmx.net, julia.metzler@bbsalz.at (J. Metzler).

[1] Both authors (J. Metzler and C. Tasch) contributed equally to this work.

https://doi.org/10.1016/j.amsu.2021.102662
Received 28 May 2021; Received in revised form 1 August 2021; Accepted 3 August 2021
Available online 11 August 2021

published data in 1999 on the increased incidence of peroneal nerve injury (PNI) by ski edges treated at the Medical University of Innsbruck, Tyrol, Austria, addressing the possible causes and mechanisms of this rare but serious injury [5,6].

Therefore, the aim of this retrospective study was to analyze PNI over a period of 20 years, including patients with this injury type treated at the Medical University of Innsbruck, Tyrol, Austria from 1999/2000 to 2018/2019. The 2019/2020 and 2020/2021 season was not included because, after the outbreak of the COVID-19 pandemic in Austria, the government ordered the complete shutdown of all Austrian skiing centers in early March 2020 and a strongly limited opening in 2020/2021.

We aimed to address and evaluate if specific factors favored the occurrence of this lesion, specifically:

- Does this injury happen to both skiers and snowboarders?
- Is there a difference between "home" and "guest" skiers?
- Is there a difference between professional and recreational athletes?
- Has the incidence of PNI increased over time?
- Is there a difference between own or rented equipment?
- Are such injuries accidental or the result of a collision with another skier or snowboarder?

2. Material and Methods

2.1. Data acquisition

This is a retrospective single-center case series study over a 20 years' period. The work was approved by the local ethics committee of the Medical University of Innsbruck, Innsbruck, Austria (EK Nr: 1300/2019). The study has been registered at ClinicalTrials.gov.(IBK-peroneus_2020) https://clinicaltrials.gov/ct2/show/NCT04980937?term=NCT04980937&draw=2&rank=1.

We reviewed medical charts over a 20-year period, including all patients with a PNI after a ski- or snowboard-related accident requiring surgical intervention at the Department of Plastic, Reconstructive and Aesthetic Surgery of the Medical University of Innsbruck, Austria. All data were gained in a clinical routine context and anonymised. We only analyzed the winter seasons from 1999/2000 to 2018/2019, rather than a full calendar year.

We analyzed the demographical data, including age, gender, and citizenship, as well as included variables concerning the winter sport activity (i.e., ski or snowboard, owned or rented, self-inflicted without collision or collision caused by another skier or snowboarder, professional or recreational athlete). We also analyzed the injury itself (i.e., PNI as main injury, open or closed, motoric, sensible or both, fracture, muscle injury, complete or incomplete transection), as well as the treatment. Descriptive statistics were used to summarize and organize data. Crosstabulation tables were checked by using Pearson's chi-Squared test and Fisher's exact *t*-test for potential significances.

This case series has been reported in line with the PROCESS criteria [7].

2.2. Preoperative assessment

Patients routinely presented in the emergency room of the clinic and were seen by the plastic surgeon after undergoing initial check up and x-ray investigation. Peripheral neurological and vascular status were checked and Computer tomography scans were performed if there was the suspicion of any accompanying injury.

2.3. Surgical treatment

Operations were performed under general anesthesia with patients in a supine position or in the lateral decubitus position, the leg slightly rotated inward on a beanbag. The preexisting wound was cleaned thoroughly and extended by incision for better overview. Accompanying injuries, such as lacerations of muscles, were also treated by anatomical correct repair using sutures. Commonly, such concomitant injuries involve the peroneal muscles. The anatomical details of the region are illustrated in Fig. 1; however, the exact pattern of injured structures is dependent on the extent of the wound. The distal and proximal stump of the peroneal nerve were localized in the wound and positioned. Then, the end of the nerve was mobilized and the ends were cleaned by frugal resection until normal fascicular structures appeared. All sutures on the nerve were performed using an operation microscope.

Sufficient mobilization of the nerve end to reduce tension at the suture sites was a key point of the operation. In the case of high tension and/or retraction, even after mobilization, a nerve graft was used. High tension was considered a given if it was not possible to perform a perineurial repair with minimal tension using a 8.0 Ethilon suture (Ethicon, J&J Medical devices, Vienna, Austria). If a nerve graft was necessary, sural nerve grafts were interponated. Every operation was performed by a primary surgeon on duty, who was either a consultant or a resident under supervision of a consultant. Postoperatively, the lower extremity was placed in a cast at a 30° knee flexion with inclusion of the ankle and adequate support of the forefoot area and the toes in order to prevent a talipes equinus position of the foot and to protect the neural repair from any tension or shear force. Upon hospital discharge, the patients were transferred to their home country either ground-based or by air ambulance and instructed to consult a specialist for adequate postoperative control and care. Herein, we recommend to relieve the affected leg by using crutches for eight weeks, employing adequate thrombosis prophylaxis. Physical therapy must involve electrotherapy to prevent degeneration of muscular substances in the meantime.

3. Results

In Table 1, all measured variables are depicted. The mean age was 34 (range 10–64); 30 patients were male (88.2%), and four were female (11.8%). Fig. 2 illustrates the citizenship of all injured patients. The most striking result was, that the majority of the patients were non-Austrian citizens. (n = 33, 97.1%). The ski and snowboard variables showed that 33 of the 34 patients were recreational athletes. Only one snowboarder suffered a PNI and this accident was caused by a collision with another snowboarder. From the 21 accidental injuries without collision, only information pertaining to whether the equipment was owned or rented for nine patients was available, seven (33.3%) of whom stated that their skies were rented, while the other two (9.5%) used their

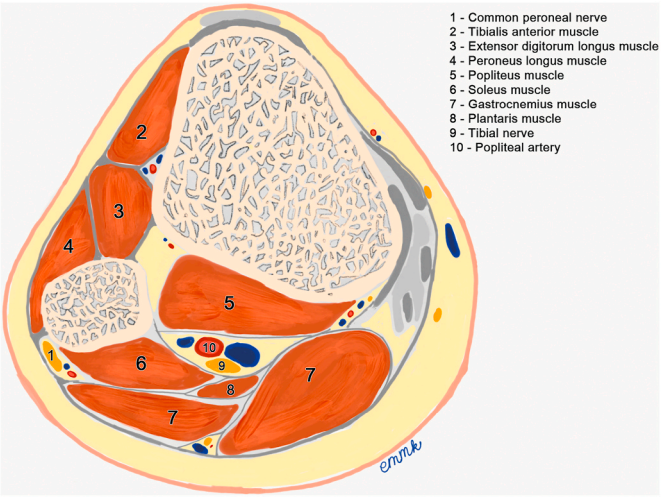


Fig. 1. Simplified anatomical cross section of the left calf at the height of the tibial tuberosity. Common Peroneal nerve (1) is depicted travelling to the ventrolateral aspect of the calf around the fibular bone. Muscles of the region are labeled in the figure.

Table 1
Measured variables in absolute numbers or percentages.

Variable	Absolute Number	%
DEMOGRAPHICS		
Age (years, mean ± SD)	34 ± 14.4	–
Gender (male/female)	30/4	88.2/11.8
Austrian/non-Austrian citizen	1/33	2.9/97.1
SKI AND SNOWBOARD VARIABLES		
Ski/snowboard	33/1	97.1/2.9
A/O/U	21/8/5	61.8/ 23.5/14.7
Own/rented/unknown	2/7/12	9.5/33.3/ 57.1
Professional/recreational athlete	1/33	2.9/97.1
INJURY		
PNI as main injury (yes/no)	34/0	100/0
Open/closed	34/0	100/0
Motoric/sensible/both	2/2/30	5.9/5.9/ 88.2
Fracture (yes/no)	2/32	5.9/94.1
Muscle injury (yes/no)	34/0	100/0
Transection complete/transection incomplete > 50% transection incomplete < 50%	25/7/2	73.5/ 20.6/5.9
TREATMENT		
EPC in a peripheral hospital (yes/no)	22/12	64.7/35.3
Definitive treatment <24 h (yes/no)	29/5	85.3/14.7
Coaptation/graft	24/10	70.6/29.4
Length of hospital stay (days, mean ± SD)	4.25 ± 1.68	–

SD, standard deviation; A, accidental injury, without collision; O, collision caused by another skier or snowboarder; U, unknown; PNI, peroneal nerve injury; EPC, emergency primary care.

own equipment.

All PNI injuries were the main injuries and open injuries, always combined with muscle injury and frequently without fracture (94.1%), indicating that the sharp ski or snowboard edges caused a relatively isolated trauma to the common peroneal nerve at the level of the fibular head (see Figs. 3 and 4). Fig. 5 shows how many patients per season during the study period were injured and surgically treated. The injury remains a rare incident without an increasing/decreasing trend.

In 24 patients (70.6%), direct coaptation was performed, and only 10 patients (29.4%) needed a graft. If grafting was necessary, the sural nerve was always interponated. In Fig. 6, the timing of definitive surgery is plotted versus the need for sural nerve grafts. The results indicate that the majority of the patients who underwent surgery within <24 h could be managed by direct coaptation, whereas delayed treatment after >24 h resulted in a relatively higher incidence of grafting. Long term outcome could not be evaluated because nearly all patients were non Austrian citizens.

4. Discussion

Several studies have addressed sports-related PNI. In a retrospective review, Cho et al. found that 18% of 448 cases of PNI were found to be sports related, the second most frequent cause after motor vehicle accidents [8]. In the 84 sports-related PNIs, skiing was the most frequent cause (50%), followed by football and soccer. Some studies describe PNI as part of a knee injury, particularly as multi-ligament with or without knee dislocation [9,10]. In their study on snow skiing versus snowboarding, DeFroda et al. reported that the incidence of the lower extremity injuries of skiers was higher than that of snowboarders; the most affected region was the knee for skiers and the lower trunk for snowboarders [11]. The specific PNI lesion is a sharp laceration caused by ski or snowboard edges. One of the largest sets of data on knee-level PNI was published by the Louisiana State University Health Sciences Center [12,13]. Analyzing the causes, they found that the most common injury mechanism was stretch/contusion in 44%, followed by tumor in 13% and laceration in 12%. Obviously, due to the region in the south of the USA, sharp lacerations resulted from other mechanisms such as broken glasses and knifes, instead of being winter sport injuries.

The most surprising result of our study was that the majority of all PNI accidents occurred in non-Austrian citizens and recreational

Fig. 3. Schematic illustration of the typical injury localization.

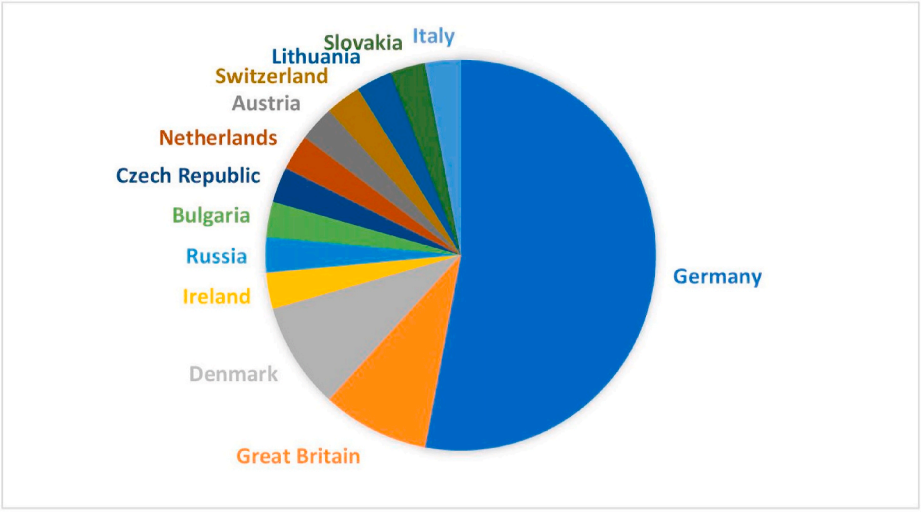
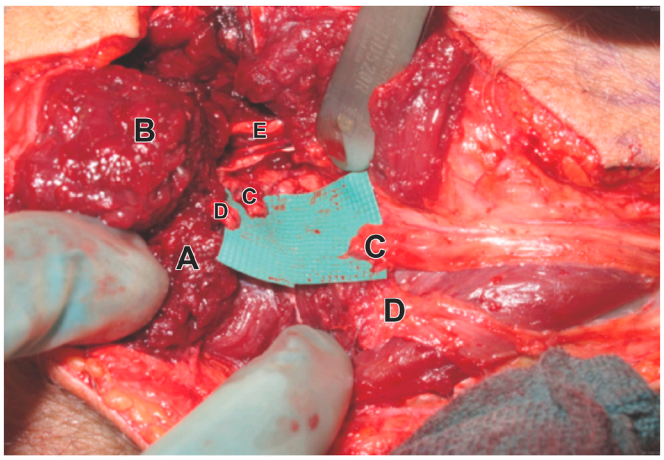


Fig. 2. Origin of the injured skiers and snowboarders.



A – Peroneus longus muscle B – Extensor digitorum longus muscle C – Deep peroneal nerve D – Superficial peroneal nerve E – Branch to tibialis anterior muscle

Fig. 4. Intraoperative view.

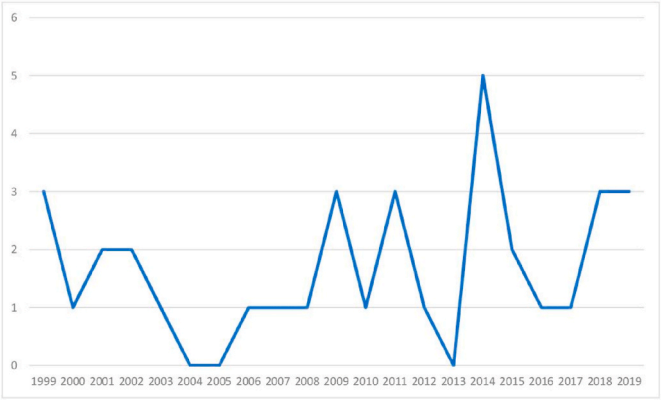


Fig. 5. The trend of PNI per season over the total study period.

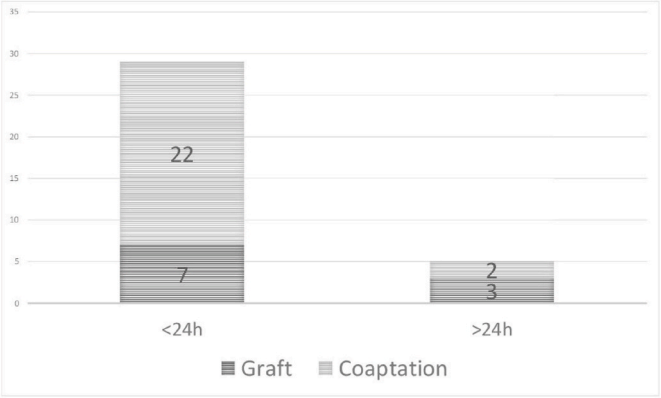


Fig. 6. Relationship between the timing of definitive surgical treatment and the need for nerve grafting.

athletes, which may be summarized as a phenomenon of "guest skiers." Guest skiers may not be familiar with the skiing area, as they typically come to the region only for vacation. Therefore, they are not familiar with the equipment, using either their own skies only for this vacation or using rented equipment or even newly bought skies, and finally, they go on skiing vacations without appropriate skills or training.

In a Scottish study, first day participants were overrepresented in the injured population by a factor of 2.2 [14]. In an Austrian study of the 2012/2013 period, Ruedl et al. found that 87% of all accidents were self–inflicted falls [15]. For analyzing our data on rented or non-rented skies, as well as collision accidents, the number of our patients was too low to allow statistical analysis. Basically, for collision accidents caused by a third party, it is of no relevance if the skies were rented or not. Obviously, in such collision accidents, PNI is caused by the edges of the other involved skier or snowboarder.

Comparing injuries associated with Alpine skiing versus snowboarding, the injury rates of snowboarders fluctuate over time, but remain higher than in skiers and affect the wrists, shoulders, and ankles, while knee ligament injuries are more common in skiers [16]. In their case report in 1999, Wechselberger et al. discussed the role of new carving skies in PNI [6]. In our 20-year retrospective study, we did not evaluate the ski type, because we can assume that at the beginning of our study period, carving tailored skies had already been introduced and were used by the majority of skiers [17].

Per se, the vulnerability of the peroneal nerve is well known. Evaluating peripheral nerve injuries in the lower extremities, the peroneal nerve itself is more susceptible to injuries than the tibial nerve due to its superficial anatomic position passing over the bony prominence of the fibular head and through a fibrous passage [18].

The timing of surgery and type of intervention for PNIs have been described for many years. In 1991, Wood described the management of sharp lacerations with end-to-end sutures within a few days of injury if sufficient coverage or vascularity is present [19]. Later studies discussed the need for grafts, the timing of surgery, and their influence on the outcome [20]. This is not an issue in the case of acute laceration injury of the peroneal nerve with a clear indication for immediate surgical intervention as early as possible. In our study, there seemed to be a trend towards the more frequent need for grafts after a relatively "delayed" intervention of >24 h when the transected peroneal nerve retracts.

Most studies concerning PNI include fewer patient data. In 1996, Kim and Kline included in their study 276 patients with PNI, of which 183 required surgical intervention; 17 were treated with end-to-end suture repair, 86 patients with a nerve graft and the rest with neurolysis. They described a significant correlation between the outcome and the length of the nerve graft. In 75% of patients the outcome was good when nerve grafts were shorter than 5.5 cm [21].

In 2005, Roganovic evaluated the outcome of 157 patients with complete missile-caused lesions of the peroneal nerve or its divisions. From the 90 patients with intermediate-level (above the popliteal crease) lesions, 31.1% had a successful outcome. However, in his study, the outcome began worsening with nerve defects larger than 4 cm and a preoperative interval greater than three months [20].

In 2014, George and Boyce assessed, in an extensive literature review, 28 studies (1577 repairs) and evaluated outcomes using the British Medical Research Council grading for motor recovery, where M4 or above was considered as a good outcome. It was observed that 37% had direct sutures and 36% had nerve grafts. Good outcomes were obtained in 64% of the repairs using grafts shorter than 6 cm [22].

4.1. Possible implications for the ski-wear industry

Most of the available protective wear focus on typical injuries and regions of the knees, shoulders etc. [23]. Appropriate stiffening of ski trousers at the fibular region may protect the nerve and reduce the risk of injury. Currently, such ski trousers are being not offered, and it is likely that with the low incidence of PNI, the ski-wear industry will not be interested in designing such skiing-outfits.

Ski boot binding systems are an essential part of ski equipment, designed and optimized to reduce injury [4]. International standards (ISO, ASTM, z – value, etc.) exist; however, in guest skiers, several factors may cause inappropriate functions contributing to resulting accidents.

4.2. Limitations

1. We were not able to investigate the functional long-term outcomes in this study, including recovery of the motoric or sensible function. Indeed, evaluation would be difficult because most of the patients live in other European countries, and sometimes there will be language difficulties and likely, after some years, some patients will not be attainable at all. Therefore, any conclusions regarding the adequacy of the chosen repair method are not possible.
2. Some additional interesting factors were not assessed or could not be documented, such as the influence of first-day skiing, beginners, "good" or "poor" skiers based on subjective self-assessment, and, finally, ski boot binding system failures [14,24].

5. Conclusions

Traumatic laceration of the peroneal nerve at the knee level by sharp ski or snowboard edges is a rare but severe injury, in the western part of Austria, most frequently affecting non-Austrian guest skiers, and it requires immediate surgical intervention, performed by surgeons trained in microsurgery. The causes of this injury may be multifactorial. Recommendations to reduce the risk of such an injury may follow general instructions and warnings to skiers and snowboarders regarding equipment, familiarity with the region, as well as appropriate skills and training. Further studies should focus on effective preventive strategies as well as on long term outcome after microsurgical intervention.

Ethical approval

The work was approved by the local ethics committee of the Medical University of Innsbruck, Innsbruck, Austria. (EK Nr:1300/2019).

Funding

This research received no external funding.

Consent

Before operation a written consent was given.

Declaration of competing interest

The authors declare no conflicts of interest.

Acknowledgments

The authors wish to thank all colleagues who were involved in treating those patients and contributed to this work: A.M.R, T.E., T.S., T. B., G.W., H.H., U.R., T.W., M.M., P.K., C.T., A.S., R.P., B.D.F., R.M., M.R., C.R., A.N., D.W., E.M. and R.V.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.102662.

Guarantor

Julia Metzler accepts full responsibility for the study, have had access to the data and controlled the decision to publish.

Provenance and peer review

Not commissioned, externally peer - reviewed.

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