



**HAL**  
open science

# Surgical epidemiology of Antarctic stations from 1904 to 2022: A scoping review

Cecile Tissot, Manon Lecordier, Martin Hitier

## ► To cite this version:

Cecile Tissot, Manon Lecordier, Martin Hitier. Surgical epidemiology of Antarctic stations from 1904 to 2022: A scoping review. *International Journal of Circumpolar Health*, 2023, 82 (1), pp.2235736. 10.1080/22423982.2023.2235736 . hal-04335198

**HAL Id: hal-04335198**

**<https://hal.science/hal-04335198>**

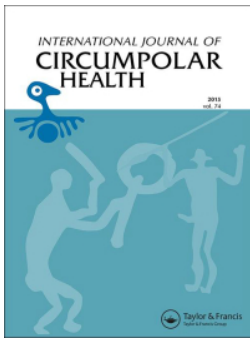
Submitted on 30 May 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License



## Surgical epidemiology of Antarctic stations from 1904 to 2022: A scoping review

Cécile Tissot, Manon Lecordier & Martin Hitier

**To cite this article:** Cécile Tissot, Manon Lecordier & Martin Hitier (2023) Surgical epidemiology of Antarctic stations from 1904 to 2022: A scoping review, International Journal of Circumpolar Health, 82:1, 2235736, DOI: [10.1080/22423982.2023.2235736](https://doi.org/10.1080/22423982.2023.2235736)

**To link to this article:** <https://doi.org/10.1080/22423982.2023.2235736>



© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



[View supplementary material](#)



Published online: 21 Jul 2023.



[Submit your article to this journal](#)



Article views: 775



[View related articles](#)



[View Crossmark data](#)

## Surgical epidemiology of Antarctic stations from 1904 to 2022: A scoping review

Cécile Tissot <sup>a</sup>, Manon Lecordier <sup>a</sup> and Martin Hitier <sup>b,c,d,e</sup>

<sup>a</sup>Faculty of Medicine and Health Sciences, UBO, Brest, France; <sup>b</sup>Department of Otolaryngology Head and Neck Surgery, Normandie Univ, Caen, France; <sup>c</sup>Department of Otolaryngology Head & Neck Surgery, CHU de Caen, Caen, France; <sup>d</sup>UNICAEN, Department of Anatomy, Caen, France; <sup>e</sup>Mobilities: Aging, Pathology, Health, Inserm, Caen, France

### ABSTRACT

In Antarctica, it is extremely difficult to organise medical evacuations in winter. Antarctic physicians are often alone and must be prepared to perform surgery and dentistry, even if they are not specialists. This scoping review summarises epidemiological data on the types of surgical procedures performed in Antarctica and identifies gaps in the literature in this area. We searched PubMed and Google Scholar, without language restriction, for papers published between 1 January 1904, and 1 February 2022. Of the 35 papers on 12 Antarctic programs, very few were retrospective observational epidemiological studies; the majority were medical reports. The search identified 41 surgical procedures or reasons for surgical consultation, 19 different reasons for medical evacuations, and 12 causes of death that may have required surgical management. The diagnostic classifications used and the prevalence of each reported surgical speciality were heterogeneous. The most cited specialities were orthopaedics, dentistry, and digestive surgery. Telemedicine was integrated into on-site care or medical evacuation decisions. The current literature is poor, and most studies do not apply to surgical issues. The heterogeneous data collection methodologies limit their interpretation. A standardised diagnostic classification and detailed and systematic epidemiological registers will help define the contours of surgical management in Antarctica.

### ARTICLE HISTORY

Received 1 May 2023  
Revised 26 June 2023  
Accepted 8 July 2023

### KEYWORDS

Surgery; medicine; epidemiology; surgical epidemiology; dentistry; Antarctica



## Introduction


The predominance of researchers in Antarctica has continued to grow since the establishment of the first official base in February 1904 [1]. Research bases now welcome nearly a thousand people in winter. This population quadruples in summer [2]. Humans have to contend with freezing temperatures [3] and winds at least as strong as hurricanes [4]. In winter, air medical evacuations are extremely complex and dangerous to organise due to the permanent darkness as well as the frozen runways and fuel (from  $-45^{\circ}\text{C}$ ). Thus, as any medical problems can quickly lead to fatal consequences, they must be anticipated. Some Antarctic programs systematically organise the medical screening of every member on their base before departure. This assessment can include dental care, chest X-ray, electrocardiogram (ECG), blood tests, and urine samples [5,6], sometimes even going so far as to perform a preventive appendectomy for future physicians [7]. After their arrival, physicians often work alone on their stations and are sometimes required to perform surgical procedures for which they are not specialists. To

better guide surgical management, knowledge of the pathologies encountered in Antarctica seems essential in order to anticipate the medical equipment required at the bases, to plan the management strategies, and to train physicians before their departure.

The objective of this scoping review is to summarise the surgical data available in the literature and to identify research gaps in surgical epidemiology in Antarctica from the establishment of the first station to the present day. To guide this study, we focused on the following research questions:

- (1) What were the population characteristics, and how were the expedition members chosen?
- (2) What was the prevalence of reasons for surgical consultation?
- (3) What types of surgery and anaesthesia were performed on site?
- (4) What were the reasons for medical evacuation and the causes of death that may have required surgical management?

**CONTACT** Cécile Tissot  [ceciletissot@orange.fr](mailto:ceciletissot@orange.fr)  Faculty of Medicine and Health Sciences, UBO, Brest, 32 rue du Général de Gaulle, 14970, Saint Aubin d'Arquenay, Normandy 29200, France

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/22423982.2023.2235736>

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

## Materials and methods

### Rationale and search strategy

This scoping review was carried out to identify existing data and research gaps regarding surgical epidemiology in Antarctica. Scoping reviews are appropriate in areas where the existing literature on a particular topic is initially uncertain. Arksey and O'Malley's methodological framework was followed [8]. The search strategy involved the systematic search of Pub Med and Google Scholar for literature published between January 1904 and February 2022, using keywords, with no language restrictions (Table 1). The year 1904 corresponds to the opening of the first permanent base in Antarctica. The references of the selected publications were also retrieved. Additional studies, not identified by the initial search strategy, were added. An initial exclusion of studies was made based on the relevance of titles. Subsequently, abstracts and full texts were reviewed for eligibility. The studies had to meet the inclusion and exclusion criteria detailed below in order to be included in the final list of publications for review.

### Selection of studies

Two reviewers (CT and ML) screened all the titles identified by the search to select potentially relevant publications. The search results and full texts of the papers were independently assessed by two reviewers. Disagreements were resolved by consensus or by referral to a third reviewer (MH).

### Inclusion and exclusion criteria

All studies, case reports, mission reports, and testimonials published from 1904 to 2022 in peer-reviewed journals related to medicine in Antarctica and reporting at least one original surgical case or reason for surgical consultation were included, without language restriction. The study was based on the definition of "surgery" according to the MeSH terminology: "operative procedures on organs, regions, or tissues in the treatment of

diseases, including the sectioning of tissues by laser" [9]. Duplicate publications, papers whose full text could not be found, and those not meeting all these criteria were excluded.

### Quality of data reporting

A data extraction table was developed. For each study, the following data were recorded: title, authors, and year of publication; type of study; period under study; stations concerned; selection strategy used for the expedition members; population characteristics (i.e. number, age, sex); number of medical consultations during the study period; diagnostic classification used; epidemiological data concerning surgery; surgical procedures performed; type of anaesthesia; pathology requiring surgery; any complications; medical evacuations; causes of death that may have required surgery; use of telemedicine and means of communication, and study limitations. The way in which the surgical gestures were defined by the authors of each study was taken into account. Their terminology was retained in the discussion of the results. An "unknown" subgroup was used to list cases related to a surgical speciality that did not describe the type of procedure or reasons for performing it.

### Ethics committee evaluation

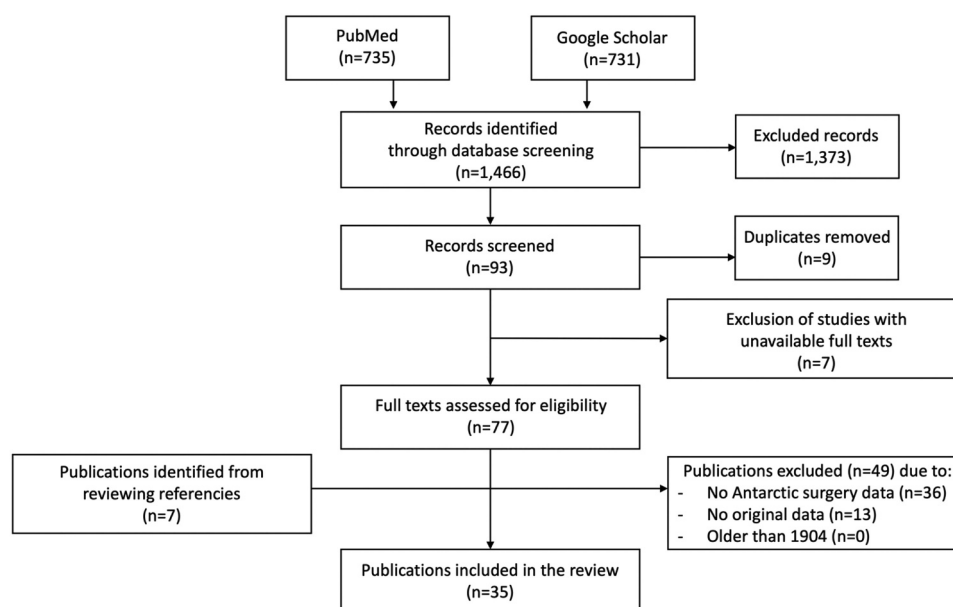
This scoping review is a non-interventional study. It preserves the anonymisation of data collected in the literature. No participants were included in the study, and no patients were exposed to any risk of physical harm, discomfort, or inconvenience. Therefore, the review was not submitted to an ethics committee for approval.

## Results

The initial search strategy identified 1,466 publications: 735 on Pub Med and 731 on Google Scholar. Of these, 77 were retained after excluding studies

**Table 1.** Keywords used for search strategy.

Database	Pub Med	Google Scholar
Keywords	(antarctic [MeSH terms] AND surgery [MeSH terms]) OR (medicine [MeSH terms] AND antarctic [MeSH terms]) OR (epidemiology [MeSH terms] AND antarctic [MeSH terms]) OR (dental [MeSH terms] AND antarctica [MeSH terms]) OR (antarctic [MeSH terms] AND emergency [MeSH terms]) OR (telemedicine [MeSH terms] AND antarctic [MeSH terms]) OR (evacuation [MeSH terms] AND antarctica [MeSH terms]) OR (case report AND surgery [MeSH terms] AND Antarctica [MeSH terms]) OR (health care [MeSH terms] AND Antarctica [MeSH terms])	"Antarctic surgery" OR "Antarctic medicine" OR "Medicine in Antarctica" OR "Antarctic epidemiology" OR "Antarctic dental" OR "Antarctic telemedicine" OR "Antarctic evacuation" OR "Polar Surgery" OR "Polar medicine" OR "Polar epidemiology" OR "Antarctica health" OR "Antarctic anaesthesia" OR "Antarctic physician" OR "Emergency Antarctic" OR "Telemedicine in Antarctica"



**Figure 1.** Flowchart.

not meeting the selection criteria ( $n = 1,373$ ), duplicate publications ( $n = 9$ ), and unavailable full texts ( $n = 7$ ). After evaluating the full texts and manually cross-checking the references, 7 new publications were evaluated. After reading all the full texts, the most frequent reason for exclusion was the absence of surgical data in Antarctica ( $n = 36$ ). The other reason was the lack of original data ( $n = 13$ ). In the end, 35 publications were included in the study (Figure 1).

### Characteristics of the reviewed publications

#### Publications type

Most publications were mission medical reports ( $n = 19$ ) [6,10–27] and retrospective descriptive observational epidemiological studies ( $n = 8$ ) [28–35]. The remainder were case reports ( $n = 5$ ) [36–40] along with a logbook report ( $n = 1$ ) [41], scientific mission report ( $n = 1$ ) [42], and scientific committee workshop ( $n = 1$ ) [43].

#### Year of publication and number of countries publishing data

The reviewed publications were published between 1958 [17] and 2020 [20]. A total of nine countries published data on surgical epidemiology: eight in Japan [18,21,22,26,29,31,35,43], seven in India [10,11,15,19,30,33,42], six in Australia [12,13,16,36,38,40], five in the United Kingdom [14,24,27,39,41], four in the United States [17,23,32,34], two in Russia [25,37], one in Ukraine [28], one in the Czech Republic [20], and one in France [6]. These publications related to 33 Antarctic and

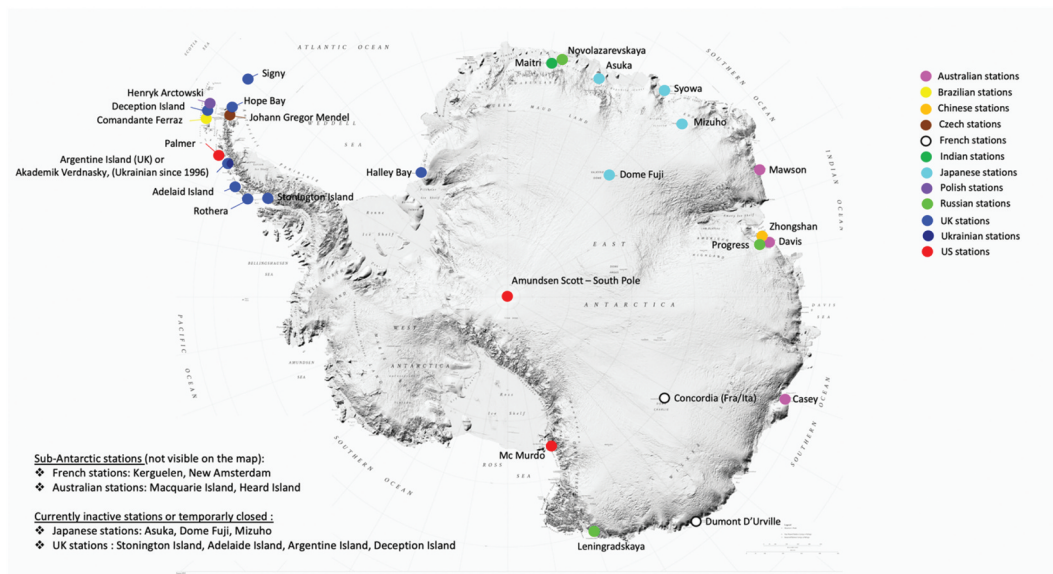
sub-Antarctic stations belonging to 12 different countries (Figure 2).

#### Periods covered by the publications

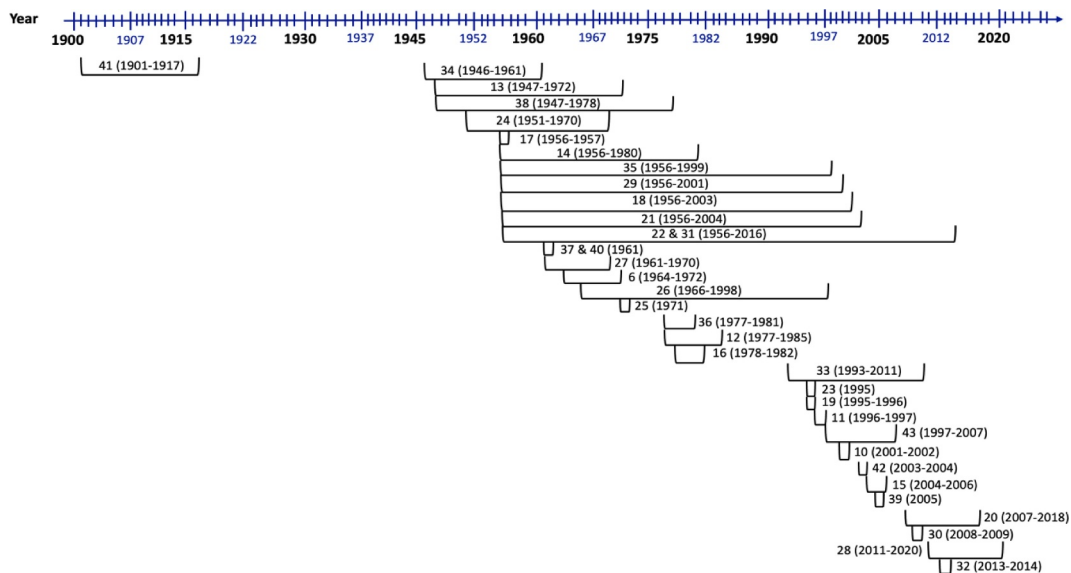
The publications covered periods stretching from 1901 to 2018 (Figure 3), although no data were reported between 1917 and 1946. The time interval studied varied in the publications from a few months [10,11,17,19,23,25,30,32,39,42] to about 60 years [22,31].

#### Medical screening and selection of expedition members

Several publications described their selection strategy for expedition members. Four studies mentioned follow-up medical visits to the general practitioner [6,30,36,38], surgeon [30], ophthalmologist [6,30], dentist and ear, nose, and throat (ENT) specialist [38], stomatologist [6], or psychological interview [18,30,38]. Personal medical and surgical history was also collected [6,36,38]. Several blood tests were performed such as a complete blood count [6,30], liver test and kidney test [30], blood sugar [6,30], serum cholesterol and triglyceride levels [6,30,38], serology (HBV, syphilis) [36,38], blood group typing [6,36], coagulation test and uric acid assay [6]. These tests could be supplemented with a urine sample by routine microscopy [6,30]. In terms of cardiorespiratory fitness, routine examinations were carried out such as an ECG, chest X-ray [6,30,36,38], and stress test if necessary [6,30]. Other complementary examinations were also mentioned in the literature such as a brain scan, electroencephalogram, abdominal ultrasound, and gastroscopy



**Figure 2.** Antarctic stations cited in the publications classified by the Antarctic program corresponding to the period under study. For example, the Hope Bay station belonged to the British program in 1970 but was transferred to the Uruguayan program from 1997. Argentine Island station was transferred to the Ukraine on 6 Feb 1996 and renamed Vernadsky. Adelaide Island was transferred to Chile 14 Aug 1984 and renamed Teniente Luis Carvajal Villarroel Antarctic Base [2,44].



**Figure 3.** Time periods covered by the reviewed publications.

[18]. In addition, one publication [28] described a set of medical examinations combined with clinical-biological parameters measured specifically to assess physiological variations during this mission.

### Population characteristics

Overall, 20 publications described the characteristics of the populations present on the bases such as the number of people, average age, and sex [12–14,16–18,20,22,23,26,28–35,42,43] (excluding case reports).

Seven publications [18,23,26,29,31,33,35] reported the presence of women on the bases. Quantitatively, in the Japanese Antarctic Research Expedition (JARE), 5% of members were women from 2002 to 2015 [18] compared with only 3 women out of 1,236 members from 1956 to 2001 [29]. In the JARE, there were 2 women out of 1,156 members from the 1st to 39th expedition, followed by 27 women out of 578 members from the 40th to 56th expedition [31]. In 1995 in McMurdo, there were 63 women out of 244 members [23]. In the Indian Scientific Expedition to Antarctica (ISEA), a total of 2



women and 325 men were present on the 13th, 15th, 17th, 22nd, 24th, 27th, and 29th expeditions [33]. In 1998, it was mentioned that there were 7 women out of 28 members in Amundsen-Scott South Pole station, 4 women out of 19 members in Mawson, 2 women out of 16 members in Arctowski, and 2 women out of 39 members on the 39th JARE expedition [26]. In other publications, men were exclusively present [13,16,17,28,35].

The age of expedition members on the bases was mentioned in seven studies. The Akademik Vernadsky station reported an average age of 37 years (range: 20 to 60 years) during 20 expeditions [28]. The JARE reported an average age of 34.1 years during the 1st to 56th expeditions from 1999 to 2016. After the 38th expedition, the average age ranged from 35 to 39 years [31]. For the 39th JARE expedition, the average age was 36.5 years (range: 24 to 57 years) [35]. JARE members had an average age of 37 years in 2015 [18] compared with 33 years (range: 21 to 56 years) from 1956 to 2001 [29]. Finally, the ISEA reported an average age of 43 years (range: 27 to 59 years) in 2008 and 2009 during its 27th expedition [30]. In a 1998 survey of 14 stations, Syowa Station reported an average age of 35.1 years (range: 25 to 56 years). For Halley Bay and Rothera, the age of expedition members ranged from 23 to 41 years [26].

Only one publication [30] detailed the comorbidities of 9 out of 26 expedition members as well as their treatment and any modifications made before the mission. For two diabetic patients, their treatment was adapted. One patient initially on homoeopathy for haemorrhoids took a cream with beclomethasone, phenylephrine, and lidocaine. Another patient with poor oral health received antibiotic treatment with cephalexin. Five other patients with arterial hypertension (2 patients), chronic lower back pain (1 patient), gingival hyperplasia (1 patient), and cerumen plugs (1 patient) received advice or kept their initial treatment.

### **Diagnostic classifications used**

The classifications used for medical-surgical diagnoses were only specified in four publications. Two were based on the International Classification of Disease, version 10 (ICD-10) [33] and ICD-1975 [14]. The third was based on the International Statistical Classification of Diseases, Injuries, and Causes of Death 1955 [13]. The last publication used a non-standard classification

created by the author [35]. Regarding dentistry, no publication included a reference for the classification of surgical procedures.

### **Surgical gestures and reasons for surgical consultation**

Nine surgical specialities were identified in this review. For each speciality, the surgical procedures performed, the reasons for surgical consultation, and the type of anaesthesia are reported below. A total of 41 surgical procedures or reasons for surgical consultation were identified (Table 2). The category “surgery” was cited in four publications [21,22,33,43] and “surgery and trauma” in 10 publications [12,13,18,25,26,28,29,34,35], although it was not possible to precisely define the relevant surgical specialities. The prevalence of the “surgery” category varied from 13% to 20% across all consultations [21,22]. Regarding the category “surgery and trauma”, its prevalence varied from 1.2% to 52% [28,34].

### **Orthopedic surgery**

Among the 25 papers dealing with orthopaedic surgery, 15 types of surgical interventions or reasons for surgical consultation were identified, excluding the “unknown” category. The three most cited categories were frostbite [12,18,19,25,27,29,30,34,35], fractures [12–14,18,19,23,27,34,35], and wounds [10,12,15,27,30,31,33,35,41]. The type of anaesthesia was not systematically described, although some procedures were performed under general anaesthesia such as the partial amputation of a big toe, the reduction of femoral fracture [19], several other toe amputations, and “foot repair with joint damage” [41]. No complications were described.

### **Digestive surgery**

Among the 18 papers dealing with digestive surgery, seven types of surgical intervention or reasons for surgical consultation were identified, excluding the “unknown” category. The most cited was appendectomy or appendicitis [6,13,14,22–24,26,27,30–32,35,37,41,42] followed by haemorrhoids [12,27,30,31,35]. The reported prevalence ranged from 0.1% to 2% of all consultations [12]. A few publications described procedures performed under general anaesthesia such as laparotomy with drainage for abdominal pain complicated by oedema with hypoproteinemia and oral and gastrointestinal candidiasis [36] as well as several appendectomies [24,41,42].

**Table 2.** List of surgical procedures or reasons for surgical consultation listed in the literature.

Surgical speciality	Surgical procedures or reason for consultation	Numbers of publications per item	General anaesthesia
Orthopedic	Incision & drainage of pus from ankle	n = 1 [11]	Partial amputation of the big toe [19], and other toes [41]  Femoral fracture reduction [19]             Foot repair with joint damage [41]
	Amputation (toes, big toe, not detailed)	n = 5 [12,13,19,27,41]	
	Fractures (tibia/fibula, medial malleolus, limbs, facial bones, vertebrae, arm, thorax, pelvis, femor, mandible, wrist)	n = 9 [12–14,18,19,23,27,34,35]	
	Dislocation	n = 2 [12,23]	
	Animal bites	n = 2 [12,27]	
	Nerve damage	n = 1 [12]	
	Foreign bodies	n = 5 [12,27,30,31,35]	
	Superficial and deep wound	n = 9 [10,12,15,27,30,31,33,35,41]	
	Tendon injuries	n = 1 [12]	
	Exostosis	n = 1 [13]	
	Frostbite	n = 2 [13,27]	
	Soft tissue infection	n = 1 [30]	
	Nail trauma	n = 1 [30]	
	Crushed member	n = 1 [27]	
	Not detailed – unknown	n = 16 [6,12,13,18,21,22,25,26,29–33,35,38,43]	
Digestive	Inguinal hernia	n = 2 [12,27]	[36]   [24,41,42]
	Hemorrhoids	n = 5 [12,27,30,31,35]	
	Laparotomy & drainage	n = 2 [27,36]	
	Gastrointestinal bleeding	n = 1 [36]	
	Appendicitis	n = 15 [6,13,14,22–24,26,27,30–32,35,37,41,42]	
General	Bleeding duodenal ulcer or ulcerative colitis	n = 2 [27,38]	
	Peritonitis	n = 1 [24]	
	Not detailed – unknown	n = 16 [12,13,18,21,22,25–33,35,43]	
	Tumor removal	n = 1 [10]	
	Polytrauma	n = 3 [14,22,26]	
	Skin tumour	n = 2 [31,35]	
Eye surgery	Sebaceous cyst	n = 1 [27]	For enucleation of an eye due to a foreign body [24]  For enucleation of a traumatic eye [41]
	Breast tumour	n = 1 [27]	
	Not detailed – unknown	n = 5 [21,22,28,33,43]	
	Eye injuries due to foreign bodies	n = 5 [15,24,27,31,35]	
	Eye injuries after blunt trauma	n = 3 [19,35,41]	
Urological	Not detailed – unknown	n = 12 [6,12,18,21,22,28–31,33,35,43]	
	Urolithiasis	n = 3 [13,32,35]	
	Vesicostomy	n = 2 [26,31]	
ENT	Not detailed – unknown	n = 7 [13,21,22,28,29,31,35]	
	Pharyngeal foreign bodies	n = 2 [31,35]	
	Epistaxis	n = 1 [12]	
Neurosurgery	Facial trauma	n = 1 [27]	For craniotomy, aspiration [40]
	Not detailed – unknown	n = 10 [21,22,28–33,35,43]	
	Intracranial haemorrhage due to aneurysm	n = 3 [13,24,40]	
Thoracic	Subarachnoid haemorrhage due to cerebral aneurysm	n = 1 [27]	
	Chest drainage for bronchial occlusion after inhaling foreign body	n = 1 [39]	
Dentistry	Dental fillings (caries)	n = 7 [11,14–16,27,31,35]	[41]
	Tooth restoration (fracture, amalgam)	n = 5 [16,17,20,31,35]	
	Incision & drainage (abscesses)	n = 2 [16,27]	
	Dental extraction	n = 4 [16,17,27,41]	
	Light astrigent treatment	n = 1 [17]	
	Not detailed – unknown	n = 16 [12,13,18,21,22,25–33,35,43]	

### General surgery

Among the 18 publications dealing with general surgery, five types of surgical intervention or reasons for surgical consultation were identified, excluding the “unknown”

category. These procedures could not be classified according to a particular speciality as in the case of polytrauma, breast tumour removal, or cyst removal [10,14,21,22,26–28,31,33,35,43]. One publication reported



the prevalence of general surgery to be 26% of consultations [30]. General anaesthesia and complications were not reported for this category.

### **Eye surgery**

Among the 16 papers dealing with eye surgery, two types of surgical intervention or reasons for surgical consultation were identified, excluding the “unknown” category. The procedures mainly concerned intraocular foreign bodies [15,24,27,31,35] and trauma [19,35,41]. Two publications mentioned the enucleation of a traumatic eye under general anaesthesia between 1907 and 1909 during the Nimrod expedition as well as an eye infected by a foreign body in 1951 [24,41]. No complications were reported.

### **Urological surgery**

Among the 10 papers dealing with urological surgery, two types of surgical intervention or reasons for surgical consultation were identified, excluding the “unknown” category: a vesicostomy for urinary retention [26,31] and urolithiasis management [13,32,35]. No publication mentioned surgery under general anaesthesia or any complications.

### **ENT surgery**

Among the 10 papers dealing with ENT surgery, three types of surgical intervention or reasons for surgical consultation were identified, excluding the “unknown” category. These related to the removal of pharyngeal foreign bodies [31,35], the management of epistaxis [12], and facial trauma [27]. One publication reported the prevalence of ENT surgery to be 0.10% of consultations [12]. No publication mentioned surgery under general anaesthesia or any complications.

### **Neurosurgery**

Among the four papers dealing with neurosurgery, one case of recurrent subarachnoid haemorrhage on the right common carotid artery aneurysm was mentioned on Halley Bay and had been evacuated [27]. On Mawson station, one intracranial haemorrhage on aneurysm of the anterior communicating artery required craniotomy and aspiration under general anaesthesia [13,24,40]. This intervention was complicated by the recurrence of symptoms, requiring a new aspiration on the 32nd day; the patient experienced an epileptic seizure and confusion on the 45th day, requiring medical evacuation.

### **Thoracic surgery**

Only one publication reported the insertion of a chest drain for bronchial occlusion following the inhalation of a foreign body [39]. The type of anaesthesia was not mentioned. The

patient would have had subcutaneous emphysema before the insertion of the drain, although no complications were reported.

### **Dentistry**

A total of 22 papers mentioned surgical dental procedures, excluding the “unknown” category. The three most cited categories were the management of decayed or abscessed teeth [11,14–16,27,31,35], post-traumatic dental restorations [16,17,20,31,35], and dental extractions [16,17,27,41]. More than half of the publications reported the prevalence of dental surgery to range from 0.1% to 51.5% of consultations [12,13,17,18,21,22,25,26,28–33,35,43]. The use of general anaesthesia was described for dental extractions [41]. Some dental abscesses were complicated by alveolar osteitis [17].

### **Reasons for medical evacuations (MEDEVAC) for surgery**

Overall, 14 publications described medical evacuations for possible surgical management [11, 13, 14, 18, 19, 22, 24, 26, 27, 32, 36,38–40]. Two evacuation strategies were identified. The first involved evacuating patients from one Antarctic station to another. This was the case of the Russian station of Novolazarevskaya, which transferred patients to the Indian station of Maitri in the absence of a physician available to provide dental care [11]. The second strategy was to evacuate patients from the Antarctic continent [18,19,22,24,26,27,36,38–40]. Several publications mentioned such evacuations without specifying the place of arrival [13,14,26,32,38] (Table 3).

### **Importance of telemedicine**

The use of telemedicine was mentioned in 13 studies [14,18,21,24,26–28,30,36,38–40]. The grounds for obtaining telemedicine services related to the provision of assistance with on-site care or the logistical discussion of a medical evacuation. Intercontinental calls were directed towards centres specialised in telemedicine [21,24,26,36,38,39] or towards national centres with a doctor with the required speciality [18,27,28,40]. It was also possible to seek advice from a doctor at a nearby station [14,19,30]. The cited means of communication were radio [14,36,38,39], radio telegram [24,40], and telephone or fax [26]. More recent means of communication included satellite television [18].

Only one publication mentioned the frequency of use of telemedicine services. Syowa station reported that it organises a monthly consultation. The base physician sends medical reports to a doctor in the home country who responds with specialised advice and information [21]. Some of these medical opinions led to medical evacuations: a case of abdominal pain

**Table 3.** List of MEDEVAC reasons for surgery in Antarctica and their destination from 1904 to 2018.

Surgical speciality	Pathologies	Reference number	Departure station	Arrival point	
Orthopedic	Pelvic fracture	[18]	Syowa	Japan	
		[26]	JARE station	NR	
	Femur fracture	[18]	Syowa	Japan	
		[19]	Maitri	India	
	Polytrauma: one case of femur and cervical fracture, one case of pelvic fracture and ureter injury		[22]	Syowa	Japan
	Tibiofibular fracture	[13]	Casey OR Mawson OR Wilkes	NR	
	Fracture of the medial malleolus	[13]	Casey OR Mawson OR Wilkes	NR	
	Exostosis of humerus	[13]	Casey OR Mawson OR Wilkes	NR	
	Facial and spinal trauma	[14]	Halley Bay	NR	
	Unspecified trauma	[32]	McMurdo	NR	
	Fall into a crevasse	[38]	ANARE station	NR	
Digestive	Gastrointestinal haemorrhage	[31]	JARE station	NR	
		[36]	Davis	Christchurch (New Zealand)	
	Abdominal pain explored by laparotomy and drainage	[36]	Casey	Australia	
	Appendicitis	[13]	Casey OR Mawson OR Wilkes	NR	
		[26]	Wilkes	New Zealand	
	[32]	McMurdo	NR		
Urological	Ulcerative colitis	[27]	Argentine Island	Argentina	
	Kidney stone	[13]	Casey OR Mawson OR Wilkes	NR	
		[32]	Wilkes	NR	
ENT	Cystostomy on prostatic hypertrophy	[26]	Amundsen Scott	NR	
	Inhaled foreign body	[39]	Syowa	Montevideo (Uruguay)	
Neurosurgery	Intracranial haemorrhage due to aneurysm	[13,24,40]	Rothera	Christchurch (New Zealand)	
	Subarachnoid haemorrhage due to cerebral aneurysm	[27]	Mawson	London (United Kingdom)	
Dental	Dental care	[11]	Novolazarevskaya	Maitri (Indian station)	
Not detailed	No diagnosis	[13]	Casey OR Mawson OR Wilkes	NR	

Note : JARE: Japanese Antarctic Research Expedition, ANARE: Australian National Antarctic Research Expedition, NR: Not Reporter, ENT: Ear, Nose, Throat.

[36], a perforated duodenal ulcer [38], a femoral fracture [19], repeated subarachnoid haemorrhages due to cerebral aneurysm [27], enucleation [24], and intracranial aneurysm [13,24,40].

### Causes of death that may have required surgery

Seven studies reported cases of death that may have required surgery. The leading causes of death were due to accidents such as tractor accidents [13,14,22,26,28], airplane accidents [26,34], climbing [13], falling into a crevasse [26,27,34], parachute jumps, and toboggan crossings [26]. Neurological and digestive pathologies such as appendicitis, cerebral haemorrhage [13,38], gastric perforations [13,26,38], peritonitis [24], and ulcerative colitis [27] were also reported.

### Study limitations according to the publication authors

The study limitations most often cited by the authors themselves related to a lack of precision in the medical

reports written during the missions [12,14,31,32] and the absence of an adequate and uniform classification of health problems [13,14,31,32], thus making any comparisons difficult.

### Discussion

This scoping review identified 35 publications from 12 countries reporting surgical epidemiological data on the Antarctic continent. The vast majority of the periods studied were after 1945. The publications were mostly medical reports and mission reports. The review identified 41 surgical procedures or pathologies requiring surgical consultation (for orthopaedic, digestive, general, ophthalmological, urological, ENT, neurosurgical, thoracic, and dental pathologies), 19 different reasons for surgical evacuations, and 12 reasons for death that may have required surgical treatment. The prevalence identified in the publications relative to the total number of medical consultations ranged from 0.1% to 51.5% in dentistry, from 13% to 20% in surgery (without

specifying the speciality), from 3% to 92.6% in surgery and trauma, from 0.1% to 2% in digestive surgery, 0.10% in ENT, and, 26% in general surgery. Shortcomings were identified in terms of the data collection methodologies and the archiving of cases.

### **Strengths and weaknesses**

This scoping review is the first paper to map and summarise surgical epidemiological data from Antarctica. This type of study provides an overview that is not possible with more traditional systematic reviews. Nevertheless, we recognise that scoping reviews do not provide a critical and structured assessment of each included study. This review was also limited to the literature available on the internet. It therefore did not analyse all the grey literature, which could lead to a substantial underestimation of the number of cases that actually occurred. Additionally, some papers could not be included, as their full text was unobtainable. This review may therefore have missed some publications.

### **Research gaps**

First, this exploratory review identified differences in the classification of surgical conditions. None of the studies defined the term “surgery” or described the associated procedures. The surgical nature of a gesture therefore risked being determined based on the subjective criteria of the authors. In the publications, for example, wounds could be classified as surgical [30,31,35,41] or not [12,33], as could fractures [14,35]. Currently, there are no classifications of surgical procedures [45]. Some studies used the international ICD classification to classify the reasons for consultation, but the data are organised by physiological system or anatomical region without taking into account the possible surgical nature of the intervention. The authors therefore used a second classification strategy to detail the type of management [13,33,35] or described the pathologies according to the ICD classification [14].

Second, gaps were highlighted regarding the geographical coverage of epidemiological data. Only 12 Antarctic programs were represented in the publications out of a total of 30 countries present in Antarctica. Half of the papers were published by five countries, namely Japan, India, Australia, the United States, and United Kingdom. The reasons why some countries did not publish surgical data are not known. This may be due to the impossibility of providing on-site surgical care, a lack of standardisation in data collection methods, or a desire to keep data confidential.

In addition, there was significant heterogeneity between studies regarding their prevalence estimates, which could be due not only to their data collection methodology but also to the population characteristics, the medical criteria for recruitment, or differences in exposure to environmental constraints. When collecting the age and gender of expedition members, the authors did not necessarily take into account the winter or summer season. This can lead to confusion bias. Therefore, only trends can be identified after analysis of these elements. To seriously discuss these issues, it is necessary to study two teams separately. This will be the subject of a new study.

### **Characteristics of the population**

Concerning the characteristics of the population described in each publication, the male sex was clearly predominant on all the missions, if not exclusively [13,16,17,28,35]. However, the presence of women seems to be increasing [18,23,26,29,31,33,35]. In the future, this trend could be taken into account in the risk of women’s specific pathologies, as well as in the preparation of physicians. To date, only one publication mentioned the existence of a mammary surgical pathology. This was the case of Dr. Jerri Nielsen, who self-diagnosed her right breast tumour in 1999 while working at the Amundsen Scott station. She had to train a carpenter and a welder to help her perform the fine needle biopsy [46].

As for the average age of expedition members, it varied from 37 years [18] to 43 years [30], which suggests that the Antarctic population was rather young. However, this interpretation can be misleading since the age range was quite wide. In the reviewed publications, the youngest member was 20 and the oldest was 60 years [28]. This difference could have an impact in terms of comorbidities, although it remains limited due to the rigorous medical selection strategy.

### **Medical selection strategy**

Indeed, medical selection is more than necessary to avoid the occurrence of pathologies, which could have life-threatening or functional complications in this isolated environment. To date, there are no standardised medical examinations carried out before departure. Most Antarctic programs required potential expedition members to consult a general practitioner and to undergo a psychological evaluation, routine blood tests, basic cardiorespiratory analysis (ECG, chest X-ray) [6,30,36,38], and abdominal ultrasound, although some programs go so far as to request more invasive

examinations such as a gastroscopy [18]. The choice of medical examinations carried out during the selection process necessarily implies a good epidemiological record. This scoping review is therefore a starting point for future research. Lessons could also be learned from the medical selection of astronauts sent to the International Space Station, which requires candidates to carry out medical examinations adapted to their ethnicity such as gastric endoscopy for Russians and Japanese given their respective risks for gastric ulcers and gastric cancer [47].

### ***Identifying the reasons for medical evacuations***

Despite this selection procedure, medical evacuations, though rare, were sometimes unavoidable. The evacuations could be organised from one station to another, but most often they involved travelling outside Antarctica. Sometimes, it was necessary to organise the evacuation in several stages and call for international collaboration. This was the case with the repatriation of a patient with intracranial haemorrhage on Mawson; he was transferred to the Mirny and McMurdo stations before travelling to New Zealand [40]. The decision to evacuate depends on a variety of factors such as the weather conditions, the clinical stability of the patient, and the human capacities and equipment available at each base. Nevertheless, nearly 98% of medical complaints are still treated on site in Antarctica [48]. In this review, evacuations concerned more than half of the surgical specialities listed in the publications. The main reasons were orthopaedic and visceral. Greater precision in reporting the prevalence of each surgical speciality could allow us to establish correlations with the reasons for evacuation and thus improve the management of on-site care.

### ***The benefits of telemedicine in Antarctica***

The use of telemedicine makes it possible to delay evacuation for as long as possible. The lack of access to specialists in Antarctica is less problematic now due to improved telecommunications. In the past, contacts were limited to radiotelegraphy. From the 1980s onwards, satellite telecommunications were gradually introduced into the stations. Then, in the 2000s, some of them were equipped with a constant connection and the ability to send moving images [21]. In the austral winter of 2015, a Casey doctor was able to benefit from the latest telecommunications technologies in Antarctica. After fracturing his dominant hand, the doctor received a specialised medical opinion from a hand surgeon in Hobart who concluded that an immediate

reduction was necessary due to the severity of the fracture and the impossibility of evacuation in the middle of winter. The procedure was performed under local anaesthesia by non-professional surgical assistants trained before the mission. The hand surgeon provided real-time telemedical support, while an anaesthetist monitored the vital parameters [49]. The frequency of telemedicine will probably increase in the coming years due to its growing effectiveness.

Despite all the safeguards, deaths in Antarctica are still to be deplored. The causes of death that could have required surgical management were often due to poly-trauma following outdoor accidents [13,14,22,26–28,34] or otherwise complications of digestive pathologies [13,24,26,27,38]. Reducing the number of accidents could be achieved through greater prevention measures with regard to the environment-related risks.

## **Conclusion**

This is the first review to map and summarise surgical epidemiological data from Antarctica. The gaps identified in this review should contribute to the development of new well-designed studies. Harmonizing the classifications used for surgical pathologies as well as the methodology used for collecting data should be explored in order to effectively compare the surgical epidemiology of all the stations. Retrospective descriptive studies using the same indicators will help fill these gaps and better define the contours of surgical management in Antarctica, notably the population characteristics, the time scales studied, the medical equipment available at each base, the type of procedures performed, the anaesthesia used, the related complications, and the use of telemedicine. This future work will make it possible to create a centralised epidemiological database in order to improve medical preparedness, the care provided and to plan cooperatively workforce and resource allocation.

## **Acknowledgments**

We are grateful to Dr. Paul Laforêt for approving the project, to Dr. Théotime Gault for providing free access to the TAAF archives and sharing his contacts, to Dr. Laurent Bonnardot and Dr. Victoria Grace for their proofreading and suggestions.

## **Disclosure statement**

No potential conflict of interest was reported by the author(s).

## ORCID

Cécile Tissot  <http://orcid.org/0000-0002-5022-2213>  
 Manon Lecordier  <http://orcid.org/0000-0001-9023-6700>  
 Martin Hitier  <http://orcid.org/0000-0002-1323-133X>

## References

- [1] Ejército Argentino [Internet]. Argentina.gob.ar. 2017 [cited July 13, 2022]. Available at: <https://www.argentina.gob.ar/ejercito>
- [2] COMNAP [Internet]. COMNAP. [cited July 13, 2022]. Available at: <https://www.comnap.aq>
- [3] Scambos TA, Campbell GG, Pope A, et al. Ultralow Surface Temperatures in East Antarctica From Satellite Thermal Infrared Mapping: The Coldest Places on Earth. *Geophys Res Lett*. June 28, 2018;45(12):6124-33. doi: 10.1029/2018GL078133
- [4] Parish TR, Walker R. A re-examination of the winds of Adélie Land, Antarctica. *Aust Meteorol Mag*. 2006;14:108, L9-14.
- [5] Medical checklist and important medical note [Internet]. [cited 13 2022]. Available at: <https://jobs.antarctica.gov.au/jobs-in-australia/applying-for-a-position/medical-checklist/>
- [6] Doury P, Pattin S Medical problems encountered in French Antarctic missions: the value and methods of selection. In: *Polar Human Biology : The Proceedings of the SCAR/IUPS/IUBS Symposium on Human Biology and Medicine in the Antarctic* [Internet]. 1973. p. 66-70. doi: 10.1016/B978-0-433-08155-5.50010-8
- [7] Do you need your Appendix removed before you go? [Internet]. [cited July 13, 2022]. Available at: <https://www.antarctica.gov.au/about-antarctica/people-in-antarctica/health/>
- [8] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol*. 2005 Feb 1;88(1):19-32.
- [9] Surgery - MeSH Term [Internet]. 1966. Available at: <https://www.ncbi.nlm.nih.gov/mesh/81000601>
- [10] Vilku DK, Behera DPK. A Medical Note on Significant Cases during the 19th Expedition. Nineteenth Indian Expedition to Antarctica, Scientific Report. *Tech Phys*. 2004;17:273-5.
- [11] Tripathi ACP, Lai R. A Medical report for the wintering period of 15th Indian Antarctic Expedition. Fifteenth Indian Expedition to Antarctica, Scientific Report, Technical Publication. 1999;13:413-6.
- [12] Lugg DJ, Gormly PJ, King H. Accidents on Australian Antarctic expeditions 1977-1985. *Polar Record*. 1987 sept;23(147):720-5. doi: 10.1017/S0032247400008457
- [13] Lugg DJ. Antarctic epidemiology: a survey of ANARE Stations 1947-72. In publisher. *Polar Human Biology* [Internet]. Butterworth-Heinemann; 1973 cited nov 28, 2019. pp. 93-104. Available at <http://www.sciencedirect.com/science/article/pii/B9780433081555500121>
- [14] Freeland WA Antarctic medicine : 25 years at Halley Bay (1956-1980). ARMY PERSONNEL RESEARCH ESTABLISHMENT [Internet]. Available at: <https://www.lboro.ac.uk/microsites/lds/EEC/ICEE/textsearch/90articles/Freeland1990.pdf>
- [15] Bandyopadhyay DG. Common Medical Problems Encountered During 24th Indian Expedition to Antarctica (Dec. 2004 to March 2006) Twenty Fourth Indian Antarctic Expedition. *Tech Phys*. 2005;2003 (22):339-43.
- [16] Fletcher LD. Dental observations at Australian Antarctic Stations. *Aust Dent J*. 1983 oct;28(5):281-5. doi: 10.1111/j.1834-7819.1983.tb02485.x
- [17] Knoedler D, Stanmeyer W. Dental Observations Made While Wintering in Antarctica, 1956-1957. *J Dent Res*. 1958;37(4):614-622. Available at: <https://www.mmclibrary.com/wp-content/uploads/2021/12/Dental-Observations-Made-While-Wintering-in-Antarctica-1956-1957.pdf>
- [18] Ohno G, Otani S, Ikeda A. Human Beings in Antarctica. In: Kanao M, Toyokuni G Yamamoto YM editors *Antarctica - A Key To Global Change* [Internet]. IntechOpen. 2019 cited march 5, 2022. Available at: <https://www.intechopen.com/books/antarctica-a-key-to-global-change/human-beings-in-antarctica>
- [19] Anant S. Medical Report - XIV Indian Antarctic Expedition. Fourteenth Indian Expedition to Antarctica, Scientific Report. *Tech Publ*. 1998;12:357-60.
- [20] Bartakova J Peculiarities of medical care in Antarctic crews with a special respect to dentistry. In Brno (Czech Republic); 2020. p. 9-10. Available at: [https://www.researchgate.net/publication/344342469\\_Proceedings\\_Students\\_in\\_Polar\\_and\\_Alpine\\_Research\\_Conference\\_2020](https://www.researchgate.net/publication/344342469_Proceedings_Students_in_Polar_and_Alpine_Research_Conference_2020)
- [21] Ohno G, Watanabe K, Okada Y, et al. Practical experience of telehealth between an Antarctic station and Japan. *J Telemed Telecare*. 2012 Dec;18(8):473-5. doi: 10.1258/jtt.2012.gth111
- [22] COMNAP Symposium C of M of NAP, éditeur. Proceedings of the COMNAP Symposium 2016: Winter-Over Challenges, Goa, India, 19 & 20 August, 2016. The Council of Managers of National Antarctic programs and contributors; 2016.
- [23] Hyer RN. Telemedical experiences at an Antarctic station. *J Telemed Telecare*. 1999 March;5(1\_suppl):87-9. doi: 10.1258/1357633991932702
- [24] Wilkinson DJ. The History of Anesthesia in Antarctica. *Int Anesthesiol Clin*. 2018;56(2):19-33. doi: 10.1097/AIA.000000000000185
- [25] Dosachev ID, Gusev VP. The medical geography of Leningradskaya station (Antarctica). *Polar Geogr and Geology*. 1980 Jan;4(1):50-2. doi: 10.1080/10889378009377129
- [26] Ohno G, Miyata T. Comparison of medical service systems at Syowa Station with other Antarctic stations: Medical staff, mortality and evacuation. *Antarct Rec*. 2000 March;44(1):42-50.
- [27] Lloyd RM Medical problems encountered on British Antarctic expeditions. In: *Polar Human Biology : The Proceedings of the SCAR/IUPS/IUBS Symposium on Human Biology and Medicine in the Antarctic* [Internet]. 1973. p. 71-92. Available at: doi: 10.1016/B978-0-433-08155-5.50011-X
- [28] Moiseyenko YV, Sukhorukov VI, Pyshnov GY, et al. Antarctica challenges the new horizons in predictive, preventive, personalized medicine: preliminary results and attractive hypotheses for multi-disciplinary



- prospective studies in the Ukrainian “Akademik Vernadsky” station. *EPMA Journal*. 2016 Dec;7(1):11.
- [29] Otani S, Ohno G, Shimoeda N, et al. Morbidity and health survey of wintering members in Japanese Antarctic research expedition. *Int J Circumpolar Health*. 2004 sept;63(sup2):165-8. doi: [10.3402/ijch.v63i0.17890](https://doi.org/10.3402/ijch.v63i0.17890)
- [30] Bhatia A, Pal R. Morbidity Pattern of the 27th Indian Scientific Expedition to Antarctica. *Wilderness Environ Med*. 2012 sept;23(3):231–238.e2. doi: [10.1016/j.wem.2012.04.003](https://doi.org/10.1016/j.wem.2012.04.003)
- [31] Ikeda A, Ohno G, Otani S, et al. Disease and injury statistics of Japanese Antarctic research expeditions during the wintering period: evaluation of 6837 cases in the 1st–56th parties – Antarctic health report in 1956–2016. *Int J Circumpolar Health*. April 30 2019[cited April 30, 2020];78(1): 1611327. doi: [10.1080/22423982.2019.1611327](https://doi.org/10.1080/22423982.2019.1611327)
- [32] Pattarini JM, Scarborough JR, Lee Sombito V, et al. Primary Care in Extreme Environments: Medical Clinic Utilization at Antarctic Stations, 2013–2014. *Wilderness Environ Med*. 2016 March;27(1):69-77. doi: [10.1016/j.wem.2015.11.010](https://doi.org/10.1016/j.wem.2015.11.010)
- [33] Bhatia A, Malhotra P, Agarwal A. Reasons for medical consultation among members of the Indian Scientific Expeditions to Antarctica. *Int J Circumpolar Health*. Jan 31, 2013;72(1):20175. doi: [10.3402/ijch.v72i0.20175](https://doi.org/10.3402/ijch.v72i0.20175)
- [34] Hedblom EE. The Medical Problems Encountered in Antarctica. *Mil Med*. 1961 Nov;126(11):818-24. doi: [10.1093/milmed/126.11.818](https://doi.org/10.1093/milmed/126.11.818)
- [35] Ohno G, Miyata T. Morbidity of wintering-over participants in the first to thirty-ninth Japanese Antarctic research expeditions: analysis of 4233 cases (in Japanese). *Antarct Rec*. 2000;44(1):1-13.
- [36] Priddy RE. An “acute abdomen” in Antarctica: The problems of diagnosis and management. *Med j Aust*. 1985 August;143(3):108-11. doi: [10.5694/j.1326-5377.1985.tb122834.x](https://doi.org/10.5694/j.1326-5377.1985.tb122834.x)
- [37] Rogozov V, Bermel N. Auto-appendectomy in the Antarctic: case report. *BMJ*. 2009;339:b4965. doi: [10.1136/bmj.b4965](https://doi.org/10.1136/bmj.b4965)
- [38] Podkolinski MT, Semmens K. INTESTINAL HAEMORRHAGE IN ANTARCTICA: A MULTINATIONAL RESCUE OPERATION. *Med j Aust*. 1979 sept;2(6):275-7. doi: [10.5694/j.1326-5377.1979.tb125705.x](https://doi.org/10.5694/j.1326-5377.1979.tb125705.x)
- [39] Coldron J. Management of a Respiratory Emergency in the Antarctic Winter: A Case of Foreign Body Aspiration. *Wilderness Environ Med*. 2007 june;18(2):120-6. doi: [10.1580/06-WEME-CR-017R2.1](https://doi.org/10.1580/06-WEME-CR-017R2.1)
- [40] Pardoe R. A RUPTURED INTRACRANIAL ANEURYSM IN ANTARCTICA. *Med j Aust*. 1965 mar;1(10):344-50. doi: [10.5694/j.1326-5377.1965.tb71701.x](https://doi.org/10.5694/j.1326-5377.1965.tb71701.x)
- [41] Guly HR. Surgery and anaesthesia during the heroic age of Antarctic exploration (1895-1922). *BMJ*. Dec 17 2013;347(dec17 4):f7242-f7242. doi: [10.1136/bmj.f7242](https://doi.org/10.1136/bmj.f7242)
- [42] Hanchinal A. Important Events of the Twenty Second Indian Antarctic Expedition. Twenty Second Indian Expedition to Antarctica, Scientific Report. *Tech Publ*. 2008;20:1-13.
- [43] Proceedings of the 14th International Congress on Circumpolar Health, July 11-16, 2009, Yellowknife, Canada. *Int J Circumpolar Health*. Dec 21, 2010;69(sup7):1-598. doi: [10.1080/22423982.2010.11864609](https://doi.org/10.1080/22423982.2010.11864609)
- [44] British Antarctic Survey. History of British stations and refuges. Available at: <https://www.bas.ac.uk/about/about-bas/history/british-research-stations-and-refuges/>
- [45] Costas-Chavarri A, Meara JG. Need for a standardised procedure classification system in global surgery. *BMJ Glob Health*. 2016 Sept 2;11:e000034. doi: [10.1136/bmjgh-2016-000034](https://doi.org/10.1136/bmjgh-2016-000034)
- [46] Physician Recalls Breast Cancer Battle at the South Pole. *Oncology NEWS International* [Internet]. juill. 2001 [cited Sept 17, 2022];10(7). Available at <https://www.cancernetwork.com/view/physician-recalls-breast-cancer-battle-south-pole>
- [47] Gray WG, Johnston SL III, Saary J, et al. Medical evaluations and standards. In: *Principles of Clinical Medicine for Space Flight* [Internet]. 2<sup>ed</sup>. New York, NY: Springer; 2019. pp. 357-65. <https://link.springer.com/book/10.1007/978-1-4939-9889-0>
- [48] Mills GH, Mills CN. Challenges of Air Medical Evacuation from Antarctica. *Air Med J*. 2008 nov;27(6):281-5. doi: [10.1016/j.amj.2008.07.009](https://doi.org/10.1016/j.amj.2008.07.009)
- [49] When a doctor broke her hand in Antarctica, tradies had to operate. *ABC News* [Internet]. March 27, 2019 [cited august 31, 2022]; Available at: <https://www.abc.net.au/news/2019-03-28/antarctic-medicine-experience-to-be-shared/10945296>