STUDENT INTERN DISSERTATION

PAIN MANAGEMENT IN WILDERNESS RESCUE
A WESTERN CAPE PERSPECTIVE

Injuries requiring rescue from wilderness areas are typically traumatic and require intervention to relieve pain during stabilisation and extrication. Modalities for pain management have to be carefully matched to the challenging and austere wilderness environment and the medical qualification of the available caregiver. The most suitable analgesia available in our context remains effective splinting and stretcher selection, intravenous opiates and ketamine, while promising future alternatives exist, requiring further research.

ABSTRACT

Analgesia within the wilderness rescue setting has received little attention in the literature. Wilderness rescues typically involve painful traumatic injuries and often involve lengthy extractions over difficult terrain. In the Western Cape Province of South Africa, wilderness search and rescue is carried out by volunteers with greatly varying levels of medical qualification, and pain management strategies need to include modalities available to all. This paper sketches the trends in volume and type of rescue callouts, the epidemiology of injury and illness, and issues surrounding analgesia in this context.

Modalities are discussed and recommendations made for successful intervention in the field. Intravenous administration of opiates and ketamine remains the most effective pharmacological intervention for wilderness rescue analgesia. Splinting and correct stretcher selections play an important role and may be used by all levels of practitioner. Use of oral transmucosal fentanyl citrate, inhaled methoxyflurane and regional anaesthetic blocks are promising interventions, but require further research.

Pynverligting gedurende bergredding het tot dusver min aandag getrek in die literatuur. Pynlike, traumatiese beserings is tipies in die wildernis, en pasiëntvervoer moet oor moeilike terrein plaasvind. In die Wes-Kaap Provinsie word wildernis soektog-en-redding deur vrywilligers met wydverskillende mediese opleiding uitgevoer, en modaliteite van pynverligting moet aangepas word. Dié skripsie beskryf patrone van hoeveelheid en tipe reddingsoproepe, epidemiologie daarvan, en strydvrae omgaande wildernispynverligting.

Modaliteite word bespreek en aanbeveel. Intraveneuse opiate en ketamien bly die mees algemene en effektiewe middels. Spalke en toepaslike keuse van 'n draagbaar is belangrik en kan deur alle vrywilligers gebruik word. Gebruik van orale transmukosale fentaniel sitraat, ingeasemde metoksifluraan en streeks-narkose is belowend, maar kort verdere navorsing.

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INTRODUCTION & MOTIVATION

Medical personnel taking part in wilderness rescues face a variety of injuries and medical conditions predominated by traumatic injury and exposure[1,2,3]. In most cases where victims of mountaineering or other wilderness accidents require medical attention, the role of the medic is limited to stabilisation and support during transportation to a medical facility for definitive intervention. Thus, in many ways the wilderness rescue medical environment can be likened to urban prehospital care, and it is prehospital emergency care practitioners who most commonly fulfill the role of wilderness medics, regardless of whether or not their training prepares them for this activity. Unlike urban EMS, however, wilderness – and especially mountain – rescue often involves long extrication periods due to extremes of distance, terrain or weather. Although increasing use of helicopters[4, 6] in wilderness rescue is reducing this trend, situations such as technical or cave rescues and poor weather will always preclude air support. Pain management is an important facet of medical care in the field, and one which has been well documented as receiving insufficient attention[5]. Furthermore, wilderness settings present unique difficulties in administering analgesia, at all levels of care. There is a distinct paucity of literature on the subject.

This paper will examine the mountain rescue service in the Western Cape province of South Africa, especially within the mountains surrounding Cape Town. Attention is given to describing the trends in rescue volume and injury types, as well as the typical search and rescue personnel involved. With this in mind, we shall then discuss the modalities available for pain management and possible future developments and directions for research. The concepts detailed here are not only applicable to the wilderness rescue context but could assist decision making by prehospital emergency care practitioners, caregivers in remote or rural areas, during lengthy transportation of injured patients, or while away from normal medical services (such as during wilderness expeditions).

WILDERNESS RESCUE IN THE WESTERN CAPE

The Western Cape province is located at the most southwesterly tip of the African continent, and forms one of the nine provinces of South Africa. The province reflects the "Rainbow Nation" theme, being home to people of all ethnicity, language and backgrounds. Parts of the Cape Peninsula – where the city of Cape Town is located – have the highest property prices on the subcontinent despite being within a short drive of informal settlements typifying abject poverty. Capetonians pride themselves on their cosmopolitan city surrounded by two oceans and beautiful mountain peaks. These mountainous wilderness areas stretch throughout the province, and are a common focus for recreational activities such as hiking, climbing, paragliding, kayaking and mountain-biking. Tourism is one of the prime industries in the city and province, and focuses on wilderness areas – Table Mountain itself being the most well known. The mountain attracts thousands of local inhabitants and tourists every month and is surrounded on all sides by the city, making access a simple matter, and Table Mountain the area with the highest incidence of mountain rescues in the country by several orders of magnitude[6].

The provincial Emergency Medical Services (EMS) manage pre-hospital emergency care, and are of the highest standard in the country despite financial and staffing limitations, reflecting the First/Third World dichotomy. Consequently, there is an active cadre of volunteers within the EMS environment, nowhere less evident than within the search and rescue (SAR) community. Until recent years, all mountain rescue operations were conducted by volunteers from the Mountain Club of South Africa (MCSA) – an organisation originally created with the express purpose of providing rescue services on Table Mountain – with limited support from EMS. However, over the past six years the wilderness rescue services have been expanded to integrate all role-players in the field under one umbrella. The “Wilderness Search and Rescue” (WSAR) organisation was formed under the auspices of provincial EMS to provide wilderness (predominantly mountain) rescue throughout the province. This group brings together volunteer SAR teams, wilderness clubs, local law enforcement, emergency services, sea rescue and the South African Air Force, to standardise and rescue integrate procedures and services. Although many members are employed by professional public-service organisations, all perform SAR duties on a voluntary basis as “unpaid professionals”.

WSAR volunteers come from all professions and consequently have greatly varying levels of medical training. Many are laypersons with regard to medical care or have only basic first aid training, but are essential members of the team due to exceptional skill in areas such as technical mountaineering and rope rescue, helicopter operations, cave rescue, field communications, etc. Medical field personnel typically fall in one of two categories – EMS personnel who also take part in SAR, and SAR volunteers who are members of the medical profession. In the case of the former, most are basic life support (BLS) personnel, while some are advanced life support (ALS) paramedics. Unfortunately, a minority of this group are recreational mountaineers and thus there is a limitation on the nature of the terrain which may be accessed. The latter category tend to be medical professionals (mostly doctors) who are recreational mountaineers. These personnel are therefore ideally suited for inclusion in SAR teams as medics, but are unfortunately few and have professional limitations on their time available for SAR activities.

The level of medical qualification has implications for the modalities of analgesia available to the practitioner and thus the patient (see table below).

MODALITY				
METHOXYFLURANE	(Potential)	(Potential)	(Potential)	(Potential)
REGIONAL ANAESTHESIA				Available
KETAMINE				Available
OPIATES			Available	Available
IMI ANALGESIA				Available
ORAL ANALGESIA			Available	Available
VACUUM MATRESS	Available	Available	Available	Available
SPLINTING	Available	Available	Available	Available
LEVEL	**First Aid**	**BLS**	**ALS**	**Doctor**

LITERATURE REVIEW

An electronic literature search using the PubMed[7] interface was performed with the initial search phrase *"(wilderness OR mountain) AND ("pain management" OR analgesia)*" limited to human studies and the English language. Thirty-four articles were found and the abstracts reviewed for suitability to the subject matter. The search was expanded to include all languages and the terms "combat" and "pain control" within the respective search strings above. Additional articles were identified by manual search and comparison of references from the original articles. In addition, electronic searches for literature on prehospital analgesia, wilderness medicine, remote medicine, combat medicine and specific analgesic and anaesthetic intervention were performed, drawing from journals of anaesthesiology, emergency medicine, military medicine, emergency medical services and wilderness medicine. A manual search of all the Wilderness and Environmental Medicine Journal articles from 1995 to 2004 was also conducted. All locally available textbooks on wilderness medicine[8,9,10] and search and rescue[11] were reviewed for relevant content.

It should be noted that some limitations do exist upon the review above; new literature has recently (mid 2005) been published which may have bearing on the field[12]. In addition, the author did not have access to Dr Paul Auerbach's sentinel work "Wilderness Medicine[13]", which includes a chapter on pain management. However, it is felt that this does not detract from the value of this dissertation, as it has forced a de novo *review and stimulated thought regarding problems and solutions in the field.*

EPIDEMIOLOGY OF WILDERNESS RESCUE – IDENTIFYING THE CHALLENGES

The importance of analgesia as an intervention in wilderness rescue is based upon the prevalence of painful injury within this context. The trend in volume of rescue callouts – in our setting, almost exponential growth – must also be considered. Little data are available both locally and internationally on the types and incidence of wilderness injuries/illness. In a notable exception, published illness and injuries in casualties rescued by Scottish Mountain Rescue teams[1] showed that slightly more than half of all local SAR callouts resulted in the rescue of ill or injured casualties. This retrospective review of data gathered by the team and collated with regional trauma registries showed that, of a total of 622 emergency callouts over two years, 232 (37%) of persons were recovered without medical sequelae – lost, overdue or mistakenly missed – while 57 (9%) of callouts resulted in body recoveries due to fatal accidents. Observational data from the SA Mountain Accidents Database[6] show a similar distribution.

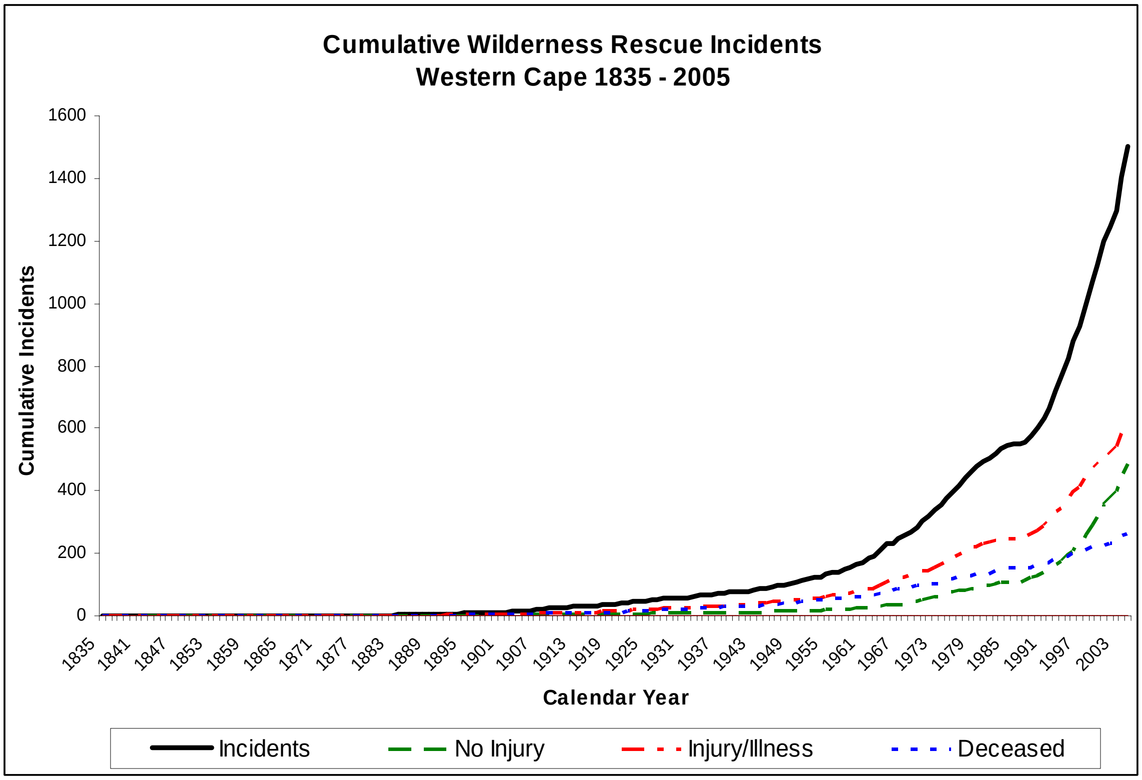

Figure 1 Graph of mountain rescue callouts in the Western Cape from 1835 to the present, showing total incidents and breakdown by incident type. The continued increase in wilderness rescues is postulated to be due to both improved communications systems – such as the availability of cellular telephony – and increasing recreational use of wilderness areas. Reproduced with permission from the SA Mountain Accidents Database[6].

Specific data on nature of injury do not exist for our region, although mechanism (activity during which injury took place) is reflected in Figure 2. These data have not been collated with hospital medical records, but show an informal similarity to that described in the Scottish study. Their findings showed that 78% (261 of 333) of casualties who survived their illnesses or injuries were suffering from traumatic injuries. Half of these had lower limb injuries, reinforcing the findings of a previous mortality study in the same area[14]. Incidence of major trauma (as defined by an injury severity score exceeding 15) was equal to that of spinal injury, at 3.6% each. Fractures and lower limb injuries are also the most common injuries resulting from paragliding accidents, with this subgroup of wilderness injuries also having a much greater incidence of spinal injuries[15].

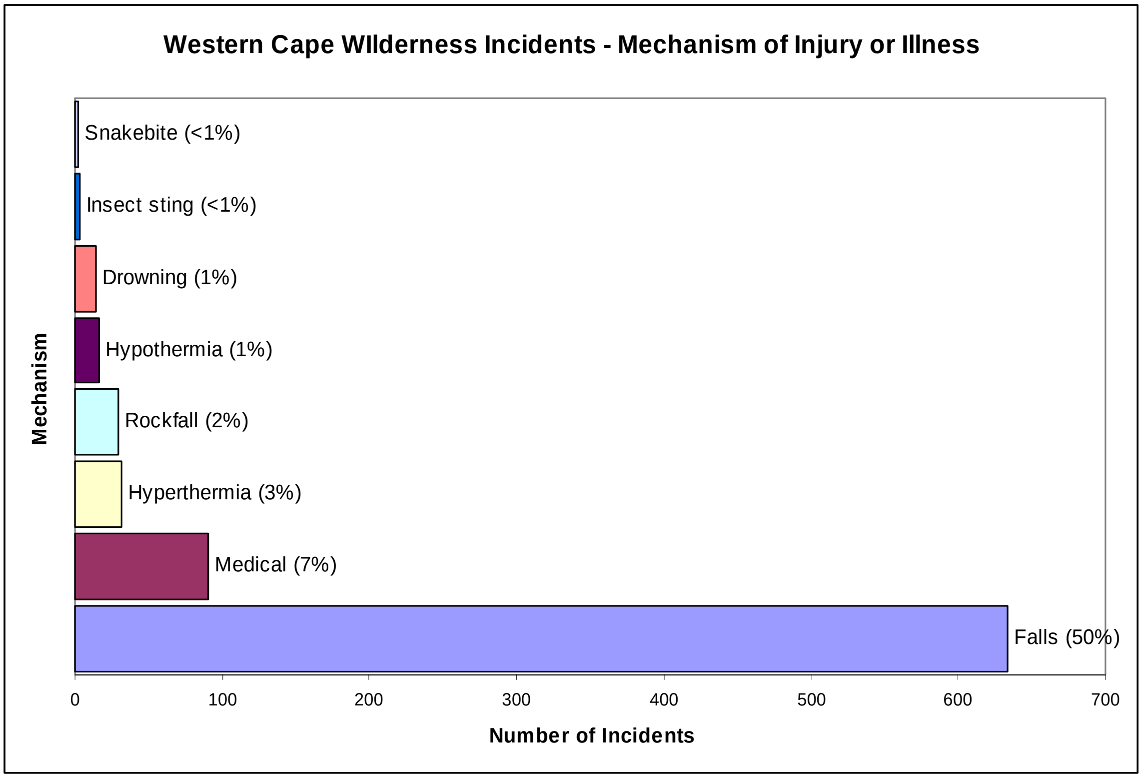

Figure 2. Mechanism of injury, illness or death in mountain accidents in the Western Cape from 1835 to the present. Percentages are of *all* rescue callouts, including those in which no illness or injury was present. The predominance of traumatic causes is obvious. Reproduced with permission from the SA Mountain Accident Database[6].

Studies of wilderness mortalities further enforce the principle that trauma is the greatest cause of illness or injury. It is noteworthy that most fatalities occur instantly or before rescue teams arrive. This has been demonstrated by both the Scottish study and a review of wilderness mortalities over 13 years in Arizona[16]. This high incidence of traumatic injury clearly demonstrates that analgesia is one of the most frequently needed interventions during medical care of injuries in the mountains.

Non-traumatic medical conditions requiring rescue in the mountains are dominated by cardiac conditions and exposure (both hypo- and hyperthermia in our context), as confirmed by the Scottish study, where 55% (42 of 76) of those rescued due to a non-traumatic condition were suffering from exposure or exhaustion alone.

ANALGESIA IN THE WILDERNESS

The remote and austere wilderness environment poses multiple challenges to providing effective analgesia. All medical supplies have to be carried to the scene of the accident; patients are frequently in awkward locations with difficult access; and adverse weather and darkness can hamper rescue efforts. The wilderness rescue doctor must be capable of traversing all forms of terrain applicable to his area of operation, particularly steep mountainous locations within our context. He or she should be self-sufficient and not rely too heavily on other team members for assistance during access and extrication, must carry his own personal equipment as well as medical supplies, and must be able to diagnose and manage illness and injuries without sophisticated diagnostic and monitoring equipment.

As previously described, traumatic injuries dominate amongst medical conditions requiring rescue. However, the injury is seldom isolated; more frequently, it is complicated by hypovolaemia due to blood loss, by dehydration, or by exposure. Concomitant head injuries are also common[1]. Medical practitioners in the wilderness do not always have sufficient lighting, a clean, open area in which to work, or readily available assistants and resuscitation equipment as do their in-hospital counterparts. It is within this challenging environment that they must provide analgesia. Perhaps the closest comparison which can be made is to the harsh combat medical care environment.

An ideal analgesic modality for mountain rescue would be effective for severe pain with rapid onset and medium to lengthy duration of action. It would have minimal side-effects and would not be contra-indicated in hypovolaemic or hypotensive patients, or in patients with head injuries. It would not require intravenous administration and could be administered by rescuers with a minimum level of medical training. Finally, an ideal analgesic would preserve patient autonomy so that they may assist with their own rescue. For instance, a patient with an isolated humerus fracture can abseil themselves provided splinting and analgesia is sufficient without reducing consciousness, negating the necessity for a highly technical rope rescue.

MODALITIES AVAILABLE FOR PAIN MANAGEMENT

Modalities of analgesia are diverse and span the scope of western and complementary medicine. "Tender Loving Care," acupuncture, acupressure[17], placebo, transcutaneous electrical nerve stimulation (TENS), intranasal and nebuslised opiates and ketamine, and transdermal analgesic patches have all been shown to have measurable analgesic effects. However, these modalities will not be discussed below as the aim is not exhaustive coverage of analgesia but rather those modalities most applicable to wilderness rescue.

SPLINTING & IMMOBILIZATION

Splinting of orthopaedic injuries is seldom mentioned as a method of pain management, but is well known to provide substantial relief[18]. Fortunately, splinting is easily learnt in the most basic of first aid courses and observation suggests that the skills are well retained. Lightweight SAM or Kramer wire splints are easily carried by mountain rescuers; the latter are more bulky but universally known in our context. The high incidence of traumatic injuries combined with the most common mechanism of injury – fall from a height – reinforces the principle that this is an important modality for use in the wilderness. Splinting should, however, be complemented by adjuvant pharmacological analgesia whenever possible.

Due to the prevalence of lower limb injuries, evacuation of wilderness casualties by stretcher is a common result of a wilderness rescue callout. Many types of stretcher exist, designed to meet the demands of varying applications from simple carry-outs to technical cliff and cave rescues. In general, two basic themes exist – rigid stretchers are usually used for technical rescues and carry-outs, while SKED-like wrap-around stretchers are more suited to canyon and cave rescues. Both types are often complimented by the concomitant use of a Kendrick Extrication Device (KED) or the weight-bearing variation, the Harness Extrication Device (HED) to provide improved spinal immobilisation. In the confined space environment of cave rescues, this allows the patient to be removed from the stretcher to negotiate restrictions without the absolute loss of immobilisation.

It should be noted that immobilisation on hard stretchers has been shown to cause pain in healthy volunteers[19]. ATLS guidelines[16] indicate that patients should be removed from hard stretchers within two hours to prevent injury due to high interface pressures. The use of a vacuum mattress in conjunction with mountain rescue stretchers has been shown to improve both immobilisation and patient comfort[20]. Although there are limitations to the use of a vacuum mattress in the wilderness – bulk and weight as well as risk of puncture and failure – observational data from rescue overseas shows that this is a useful addition to the rescue stretcher. An additional benefit is seen in canyon rescue, as a stretcher with vacuum mattress added will float even when loaded with a large patient. Due to a kind donation, WSAR does possess a vacuum mattress, although it has not yet been utilised in the field.

ORAL ANALGESIA

Oral administration is both a familiar and accessible route for analgesia, and is by far the most commonly used in general medical practice. In a conscious patient, the use of oral medication is simple; depressed consciousness is a relative contra-indication. Oral analgesics used for acute pain include the non-steroidal anti-inflammatory drugs (NSAIDs) and oral-preparation opiates, as well rarer preparations such as oral ketamine.

NSAIDs

This category includes the aspirin-like family of drugs which peripherally inhibit prostaglandin synthesis. Paracetamol, which has a central inhibitory effect, is frequently included as its actions are similar: analgesia, apyrexia and reduction of inflammation. NSAIDs are effective for mild to moderate pain, especially that of musculoskeletal origin. A plethora of preparations and combinations of NSAIDs exist and are readily available over-the-counter. Oral NSAIDs are a simple and effective intervention for patients with injuries such as muscle strains, joint pain and other conditions where inflammation is a prominent cause of discomfort. Some authors go as far as to endorse use of NSAIDs as ideal wilderness analgesics[9, 10]. However, significant barriers to the use of NSAIDs exist in the context of wilderness rescue. Renal failure (and to a lesser extent, hepatic damage) has been identified as a complication of NSAID use, as well as increased bleeding tendency due to the antiplatelet effect, and gastric mucosal damage[21]. Antiprostaglandin-mediated vasoconstriction combined with the adrenergic response to physical insult decrease renal blood flow; consequently injured and/or hypovolaemic patients - due to blood loss, dehydration or other factors - are at greatly increased risk due to a combination of this renal hypoperfusion and increased levels or circulating myoglobins. The newer cyclo-oxygenase-2 selective NSAIDs have less effect on the gastric mucosa but are no better for the kidneys. NSAIDs are therefore contra-indicated in severely injured patients. NSAIDs have also been postulated to have a negative effect on fracture healing; animal models show a negative effect but this has still to be confirmed or refuted in humans[22,23].

NSAID analgesia is subject to a ceiling effect - increasing dose beyond a given level does not increase analgesic effect, whereas side-effects are worsened. Method of administration - oral, rectal, intramuscular or intravenous - does not affect analgesic potency or decrease side effects. Onset of analgesia is seldom within 30 minutes. Consequently, NSAIDs have limited use in wilderness or mountain rescue, and should be reserved for stable euvolaemic patients with mild to moderate injuries. Oral administration should be sufficient in these cases.

Oral opiates

Several opiate drugs are available for use *per os*, usually in liquid, syrup and tablet forms. These are typically used for the management of chronic pain. Acute pain in the context of wilderness rescue is better managed by intravenous opiates[24], with the exceptions that follow. A detailed discussion of IV opiates analgesia can be found under 'Intravenous Analgesia.'

Tilidine (Valoron®) drops are particularly useful for paediatric perisurgical and procedural analgesia, but can be used in adult patients as well. Dosages are fairly simply calculated, and the drug is well absorbed sublingually with duration of action of 4-6 hours, although the onset is slower than with parenteral administration of other opiates. Patients must be alert and haemodynamically stable, as the usual opiate side-effects can occur (see below). Adult dose of Tilidine is 50-100mg (20-40 drops); for children use one droplet per year of age plus two drops to a maximum of 10 drops (25mg).

A novel to analgesia in an austere environment has been tested in a small combat study during Operation Iraqi Freedom[25]. Lollipops containing 1600µg of oral transmucosal fentanyl citrate were given to 22 haemodynamically stable soldiers with uncomplicated, isolated orthopaedic injuries or extremity wounds. Verbal numerical pain scores were recorded before administration, at 15 minutes and again at 5 hours. Adverse effects and requirement for further analgesia were recorded. A significant mean reduction in pain scores between 0 and 15 minutes (5.77, 95% CI 5.18 to 6.37) and insignificant change between 15 minutes and 5 hours (indicating sustained action) was found. Adverse effects included pruritis (22.7%), nausea (13.6%), emesis and lightheadedness (9.1% each), but were confounded by potential concomitant motion sickness (patients were extracted under combat conditions by helicopters flying at high speed following the terrain to avoid enemy action). One incidence of hypoventilation occurred in a patient who also received intravenous morphine. These “fentanyl suckers” hold potential for application in wilderness rescue, but require testing in a larger study within our context. This will be a modality to closely watch in the future.

INTRAMUSCULAR ANALGESIA

Numerous analgesics can be administered intramuscularly (IM), including some NSAIDs, most opiates and ketamine. However, the only advantage of this method is the simplicity of administration. Numerous problems with intramuscular analgesia are a barrier to its use in trauma[18] and wilderness rescue. In addition to the adverse effects of NSAIDs discussed previously, IM injection of diclofenac can result in sterile abscesses[26]. Uptake and effect of intramuscular drugs is unpredictable and often delayed in patients who are injured, hypovolaemic or cold – all prevalent in wilderness rescue. Effective titration is therefore impossible. For these reasons, IM analgesia is not recommended for use in wilderness rescue situations.

INTRAVENOUS ANALGESIA

NSAIDs

Intravenous (IV) NSAID preparations (eg. IV keterolac) are available, but are not recommended for mountain rescue for the reasons previously provided under "Oral Analgesia" and will not be discussed further.

Opiates

IV opiates remain the mainstay for relief of severe pain in both prehospital and hospital settings[27,28]. Opiates act on the central nervous system to suppress pain, resulting in analgesia without loss of consciousness. Histamine release caused by some opiates (particularly morphine) causes peripheral vasodilatation, a drop in blood pressure and potentially, nausea and emesis. In addition, central suppression of respiration occurs due to a reduction in response of brainstem respiratory centre to pCO_2. Patients who are not on respiratory support can develop a relative hypercarbia causing cerebral vasodilatation and thereby increased intracranial pressure. Head injury is thus a relative contraindication to opiate administration, although specific opiate drugs have a better side-effect profile making them more suited to use where head injury complicates management. Other side effects of opiates – such as decreased gut motility – are of less relevance for wilderness rescue.

Morphine is the reference opiate, and is well suited to managing severe pain, and is by far the most widely available and affordable. Most doctors and paramedics are familiar with morphine, although fear and resistance to its use (the so-called "opiophobia[5]") are well documented[29]. However, affects – both desirable and adverse – are predictable with titrated IV administration. Small boluses (0.01-0.02mg/kg or 1ml of 1mg/ml solution for an adult patient) are given every 5 minutes until adequate pain control is achieved. There is no true maximum dose, but the aim is rather to make the patient comfortable – as opposed to pain free – without pronounced side-effects. Onset is within 3-5 minutes, peak analgesia reached in 10-20 minutes and duration 3-4 hours. Onset of side-effects is predictable - blood pressure drop occurs within the first 2-5 minutes, and any respiratory suppression will occur within approximately 7 minutes[20].

Other opiate options include tramadol, fentanyl, afentanyl and sufentanyl. The latter two agents have similar properties to fentanyl (discussed below) but have increasingly faster onset and shorter duration of action with less cardiovascular side-effects due to diminished histamine release. These agents show great promise for wilderness rescue applications but are unfortunately expensive and rare outside of intensive care units in our context. Pethidine (meperidine) is not discussed here as it has been shown to be inferior to morphine[30].

Tramadol (Tramal®) is a weak opiate – about one-tenth the strength of an equivalent volume of morphine – which appears to work at a spinal level[27] and has the advantage of causing minimal (if any) respiratory depression. It is therefore the opiate of choice in patients with head injuries, although small-dose morphine has also been described as effective in this setting. Tramadol is also reputed to be more cardiovascular stable than morphine, with comparable onset of action and duration.

Intravenous **fentanyl** has several advantages for wilderness rescue – onset of action (almost immediate) and duration (30-60 minutes) of this synthetic opiate are quicker and the profile is more predictable. More frequent administration is required, but less histamine release and respiratory depression occur than with morphine. Fentanyl is gaining support swiftly within the prehospital and emergency medical environments[48], and is an ideal analgesic for severely injured patients in the wilderness where extraction will not be protracted or when titrated boluses can be easily administered. Dosages range from 50-100µg in divided, titrated administrations.

Mountain rescue medics should consider the administration of a small fluid bolus before opiate administration, an IV antihistamine (or antiemetic if this is not available), or the use of a combined preparation such as Cyclimorph®. Opiates should be used with caution whenever continuous monitoring of the patient by a medic is not possible, such as when performing cliff rescues. Opiates should not be added to infusions, as the risk of uncontrolled administration is greatly increased. Other methods of analgesia must be used when hypotension cannot be corrected. Despite these caveats, opiates are the primary and best existing method for wilderness analgesia during rescue.

Ketamine

"For patients with multiple injuries and for those patients requiring manipulation and splinting for fractures, and for entrapments and extrications, ketamine is a safe and effective option, which avoids the potential decrease in blood pressure and respiratory suppression that is associated with opioid analgesia." [31]

Ketamine is a unique drug, which is both a potent analgesic and disassociative anaesthetic, depending on the dose administered. At anaesthetic dosages (typically 2mg/kg, but up to 4mg/kg in children), ketamine induces a state of disassociation from the physical suffering by selectively anaesthetising the limbic system, and thus separating the patient's perception from the noxious stimuli experienced. At lower dosages (0.2-0.4mg/kg), ketamine is a potent analgesic. At all times, however, normal muscle tone and airway reflexes are maintained. Furthermore, whether at anaesthetic or analgesic doses, administration is remarkably free of the "usual" side effects of analgesia – there is a slight *increase* in cardiac output, bronchodilation, no respiratory suppression, no histamine release, no accumulation and no relevant organ toxicity. However, ketamine use is complicated by an increase in myocardial oxygen consumption, an increase in salivation, and has long been alleged to cause raised intracranial pressure[32], especially in the presence of hypercapnia. This has more recently been questioned, and ketamine was shown to have a direct neuroprotective effect with no increase in ICP in normocapnic patients[33]. Hypersalivation is frequently quoted as a side effect but is consistently uncommon in studies, as is the oft-mentioned, severe but exceedingly rare (less than 1% incidence) complication of laryngospasm. It is worth noting that laryngospasm is never described in the literature as occurring without concomitant stimulation of the larynx by either intubation attempts or suctioning[31,34].

A further potential problem with ketamine is the occurrence of an emergence delirium with what are sometimes described as hallucinations. Detailed study into the psychotropic effects of ketamine[35] has shown that these are not hallucinations, but rather illusions stimulated by a variable level of consciousness during emergence. Adjuvant administration of small doses (1-2mg) of midazolam with ketamine has been shown to reduce the incidence and severity of emergence phenomena[36].

Ketamine's advantages (cardiovascular stability, maintained "consciousness", spontaneous respiration and airway reflexes as well as wide range of dose and effect from analgesia to anaesthesia), combined with practical advantages (it does not be require refrigeration, can be kept for several years, and does not suffer quite the regulatory hassles of opiates) make it a very useful drug for wilderness analgesia. Ketamine is most predictable and effective when given intravenously, but can be administered intranasally, orally, rectally, or by intramuscular injection when necessary. Wherever possible, patients and fellow rescue staff should be warned of the outward effect and inner sensation associated with ketamine use so as to avert anxiety.

Regional Anaesthetic Techniques

Regional anaesthesia has become a topical issue in wilderness[37] and combat[38] medical care. Recent discussion in the South African Medical Journal[39] has shown polar opinions regarding this intervention.

Regional anaesthesia involves blockade of a specific nerve or nerves to prevent painful sensations reaching the brain; this includes peripheral nerve blocks and spinal anaesthesia by intrathecal or epidural injection. These techniques – especially spinal anaesthesia – are familiar to medical practitioners and are commonly performed for surgical anaesthesia in the operating theatre. Local anaesthetic solutions (e.g. lignocaine) are injected in close proximity to a nerve, preventing conduction of nerve impulses. As pain is conducted by thin nerve fibers, noxious stimuli are quickly blocked provided injection is accurate. Placement of fine catheters (in the style of an epidural) with continuous infusion or boluses of local anaesthetic have been highly successfully used for transportation and operative anaesthesia in combat casualties[40]. Data for use in wilderness rescue has not yet been published, but the technique has been highly successful in a large group of patients – without recorded adverse effects – in the hands of an experienced anaesthetist who is also a mountain rescue doctor[41].

The advantages of regional anaesthesia are clear – pain is absent or greatly reduced, systemic effects are minimal, with no sedation, respiratory depression or cardiovascular effects, and the patient's mobility is improved. However, the risks are real and multiple. Adverse reactions can be due to inadvertent intravascular administration of local anaesthetic or overdose, nerve damage due to needle trauma or injection into a nerve, pneumothorax, haemorrhage, accidental blockade of the phrenic nerve, or other complications. Furthermore, injuries preclude the use of a nerve stimulator in the field, making peripheral nerve blocks in the wilderness a challenging intervention. Spinal anaesthesia should not be attempted.

Special conditions in which peripheral nerve blocks may hold additional value include confined space rescues – for instance within caves – where the nature of the obstructions require physical manipulation which would be unbearable despite more conventional forms of analgesia. In this setting, rescues are typically protracted and require lengthy set-up time for technical extraction, affording the suitably experienced practitioner opportunity to perform the technique.

Regional blocks to be used in the field must have a maximum risk-benefit ratio; blocks which avoid "dangerous" areas are preferred. Techniques which may be considered include the brachial plexus block via the coracoid and axillary approaches, femoral three-in-one block[42] and peroneal nerve block.

Further studies of regional anaesthesia in the wilderness setting are eagerly awaited, as significant data already exist. However, significant experience is required to safely and successfully perform these techniques. It is therefore clear that regional anaesthesia in wilderness rescue should only be performed by practitioners who have developed and maintain this skill in a hospital setting on a regular basis, in settings in which there is sufficient time to perform the technique carefully and patiently.

INHALATION ANALGESIA

Entonox

Well known through usage for many years in obstetric analgesia, Entonox is a 50/50 mixture of nitrous oxide (N_20) and oxygen, which has found some support in the pre-hospital setting. The gas is delivered via a demand valve or facemask and offers the advantage of on-demand analgesia in combination with oxygen supplementation. Analgesia has been shown to equal that of morphine under the correct circumstances and use[43]. Effective analgesia, however, relies heavily on patient co-operation.

Entonox must be stored in high-pressure cylinders, which are heavy (even a small cylinder would constitute almost the full load a rescuer could add to his rucksack) and can put rescuers in a mountain environment at risk if damaged or dropped. As the gas is provided in a fixed concentration, it is also subject to a drop-off in analgesic effect at increasing altitude. At sea level, Entonox was shown to cause an increase in pain threshold of 71.5%, while at 1400m above sea level, the effect was shown to be only 40%, and at 3000m this dropped to 19%[43]. Finally, it must be taken into account that some types of injuries (such as pneumothorax) preclude the use of nitrogen due to diffusion pressure effects[44]. Thus, Entonox is of little use in mountainous environments.

Methoxyflurane

Methoxyflurane is the only volatile anaesthetic that has significant analgesic properties[45] (recalling that nitrous oxide cannot induce anaesthesia). Although not yet available in South Africa, methoxyflurane has been used at subanaesthetic doses in Australia and New Zealand for prehospital analgesia by practitioners of all levels from first aid to advanced life support. Use in EMS in the place of Entonox has met with great success, and it has seen limited use in wilderness rescue settings (*personal correspondence*).

Methoxyflurane is delivered in a novel manner – 3ml of liquid methoxyflourane is applied to a wick within a 15 cm plastic cylinder shaped like a whistle. The patient – who must be conscious and co-operative – inhales via a mouthpiece at one end, causing air to pass through the wick, allowing methoxyflurane in vapour form to enter the lungs. A one-way valve diverts exhaled air out of the device. An additional "diluter hole" gives the patient a measure of control over the inhaled concentration. The inhaler mouthpiece is designed to fit a standard facemask, while a nipple at the base allows supplemental oxygen to be added.

Onset of analgesia is within 6-8 breaths with duration after a single application lasting approximately 25 minutes[46]. Analgesia is said to be opioid-equivalent at the higher concentration; however, the method of administration allows the patient to titrate the dose to effect. Methoxyflurane alters the perception of pain, and is described to cause a feeling of disassociation or "floating free from pain," as well as a degree of amnesia.[47] It is reported to have a "pleasant, fruity smell that is well tolerated by patients[48]." The treatment can be repeated once, providing analgesia for a further 25 minutes. Total daily dose is 6ml with a total weekly dose of 15ml.

Methoxyflurane was initially used as an inhalation anaesthetic before being withdrawn after it was shown to cause rare cases of nephrotoxicity, associated with high serum inorganic fluoride ion concentrations (a product of methoxyflurane metabolism). However, the low analgesic doses do not produce these levels of fluoride ions and are reported not to cause nephrotoxicity; in more than two million applications there have been no reported adverse effects[49].

This method of analgesia holds promise for wilderness rescue applications – it is light, compact and highly portable, does not require any invasive procedures, and can be quickly administered without lengthy preparation. It is, however, limited to a maximum of two administrations or about 50 minutes, and then only in a conscious and co-operative patient. This can be used as an initial method of analgesia in a lengthy extraction, and further pain management (e.g. opiate administration) established while the patient is "covered" by the methoxyflurane.

Methoxyflurane has a vapour pressure similar to that of water, and evaporates at a similar rate. At low temperatures in the wilderness, this may cause a delay or reduction in action of the drug. Research into the effects of reduced partial pressures (i.e. altitude) on volatile anaesthetic agents has shown reduced effect at altitude[50]. However, as the analgesia is effectively titrated to effect by the patient, it is postulated that these effects will not be clinically significant with respect to methoxyflurane administration at moderate altitudes[51].

DISCUSSION AND CONCLUSIONS

The general benefits of analgesia for the patient – comfort, decreased anxiety, greater self-sufficiency, etc. – are well documented in the literature, and can be easily extrapolated to the wilderness setting. The benefits to the rescuer have not been formally researched but can be inferred – improved patient co-operation and mobility, facilitation of extrication, decreased susceptibility to hypothermia and reduction in rescuer stress. Even from a simple humanitarian perspective, we have a duty to administer effective analgesia in the wilderness.

Intravenous analgesia using opiate drugs and ketamine – based upon the type and severity of injury as well as the requirements of extraction – are currently the most effective and available interventions for analgesia in wilderness rescue within the context of the Western Cape. This is in agreement with the recommendations of the Medical Sub-Committee of the International Commission on Alpine Rescue (ICAR-MEDCOM)[52]. The findings of this paper suggest medical practitioners who are active in the field of wilderness rescue acquaint themselves with the use of morphine (due to its universal availability and ease of use) as well as fentanyl and tramadol. Adjuvant administration of fluids, antihistamines and antiemetics should always be considered

Familiarity with the use of ketamine is essential. Mountain rescue doctors should include equipment for advanced airway management in their medical kits, including portable hand suction units. Combined, synergistic administration of opiates and ketamine should be considered for patients who are stretcher-bound.

Non-medical interventions such as comforting "bedside" manner, correct splinting and stretcher selection should never be ignored and should be taught to all personnel involved in wilderness rescue, whether medical or otherwise.

The potential for oral transmucosal fentanyl citrate and inhaled methoxyflurane to be effective modalities in the wilderness should not be overlooked. Both are a step closer to the ideal wilderness analgesic discussed initially, although both have known side-effects and limitations. These should be watched and reassessed as more research becomes available.

Regional anaesthetic blocks are a very valuable intervention but should be limited to use by practitioners who develop and maintain this skill within a hospital environment. Placement of indwelling catheters may be considered in exceptional circumstances where extraction is delayed, such as during cave rescues.

DIRECTION FOR FUTURE RESEARCH

Clearly, there is a need for accurate epidemiological data for South African wilderness injuries and rescues. Current and ongoing developments within the SAR fraternity are aimed at increasing the comprehensiveness and accessibility of rescue data, but this needs to be combined with efforts to include clinical and postmortem injury data.

Much scope exists to investigate the use of the newer modalities – such as oral transmucosal fentanyl citrate and methoxyflourane – in both clinical and rescue settings. These modalities need to be examined in our context for efficacy of analgesia, incidence of adverse effects, and implications of cost. An emergency department study of both agents in comparison to current practices prior to field testing in the wilderness environment is planned by the author, provided the necessary permissions can be acquired to test in South Africa.

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