LESSONS FROM HISTORY

Dull Brains and Frozen Feet: A Historical Essay on Cold

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This essay will review historical and medical aspects of cold exposure, hypothermia, and frostbite during the Napoleonic era. The 19th century writings of Dominique Jean Larrey, Pierre Jean Moricheau-Beaupré, and others are used to provide an evocative supporting narrative to illustrate some of the cold illnesses, physiology, and theory of both an earlier era and the present time.

Medical care for over a century followed the *how* but not the *why* of treating frostbite and hypothermia slowly with snow or cold water rather than heat. There were 2 main reasons: First was a practical attempt to limit gangrene. Less known, and long forgotten, is a major rationale based on the erroneous theory of heat called “the caloric.” Because of these 2 reasons, the slow method of “cold warming” remained standard medical practice well into the 20th century. Although these recommendations are now known to be flawed, some of the reasons behind them will be discussed, along with early but correct observations on afterdrop and circumrescue collapse. There is a long backstory of treatment from 1812 to the present.

Key words: hypothermia, frostbite, history, Moricheau-Beaupré, Larrey

Introduction

This historical essay will focus on cold exposure, dull brains, frozen feet, and the words of 2 protagonists in the French Army’s ill-fated invasion into and retreat from Russia in 1812. References will be drawn heavily from the works of 2 surgeons, with glimpses of the medical theory and terminology of the era. The story, heavily edited to simplify the sometimes-convoluted original writings about both frostbite and hypothermia, will be blended with other sources and events and compared with modern-day knowledge.

Napoleon’s chief surgeon, Dominique Jean Larrey (1766–1842), developed battlefield triage, an ambulance system, and described many effective surgical techniques. Amputations were his personal forte when speed was of the essence before the development of modern—or any—anesthesia. Because of Larrey’s authority, his original book was translated widely, including into English in

1832. This version is available as a public domain book in print and online.^{1–4}

The writings of Regimental Surgeon Pierre Jean Moricheau-Beaupré (1778–1857) were more medically oriented than Larrey’s surgical emphasis. He authored insight into frostbite, hypothermia, and the many maladies that devastated hundreds of thousands of humans and horses, and nearly himself as well. Some perished by military action, but far more died from illnesses, lack of supplies, the scorched earth policy of the inhabitants, and winter. Beaupré’s first 5 chapters are specifically about cold injury and the Russian Campaign.^{5–8}

In 1812, slow warming for frostbite, with snow or cold water rather than heat, was partly based on a justifiable and practical attempt to limit aggravation of gangrene and its potential for sepsis and death. This was understandable and written about over the years. Less known, and long forgotten, was a major rationale based on physics. “The caloric” was an erroneous heat theory of French chemistry scientist Antoine Lavoisier (1743–1794) that influenced medicine and other sciences. In medical care, rubbing cold flesh with snow or cold liquids was thought to somehow slowly transfer the mysterious caloric factor to the cold body part and

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restore its vitality. For these reasons—the risk of gangrene and the theory of the *caloric*—the slow method of “cold warming” remained standard medical practice well into the 20th century until there was a paradigm shift in frostbite care pioneered by Alaskan physician William Mills and others.⁹

As for hypothermia, Beaupré revealed that its treatment, just like the more well-known remedy of his time for frostbite, also started with the bizarre application of cold rather than warmth. Although these recommendations are now known to be flawed, some of the reasons for them will be discussed, along with early but correct observations on afterdrop and circumrescue collapse, as they are called in modern terminology. There is a long medical trail from 1812 to the present.

Medical Science in the Napoleonic Era

First, a reminder about some of the medical science of the era is needed. Infections were not understood: Germ theory would not arrive until later with microbiologist Louis Pasteur (1822–1895), bacteriologist Robert Koch (1843–1910), and surgeon Joseph Lister (1827–1912). Second, the use of inhaled anesthetics was decades away, and safety even further. Amputations were often performed with just physical restraint. Third, scurvy could influence world affairs by crippling military and civilian populations. By the early 19th century, lemon juice had nearly eliminated scurvy onboard British ships, but sources of vitamin C were not available everywhere on sea or land. Scurvy was not thought to be a nutritional deficiency but a disease and was blamed for many conditions in other settings, such as famine. One axiom was as follows: “If anyone is ill, and knows not his Disease, Let him suspect scurvy.”¹⁰(pp110–215) Fourth, organs—for example, the pituitary—were not well understood. Beaupré reported diminution of smell in winter from “dryness of the pituitary membrane, or to its habitually catarrhal state.”⁸(p79) He related this somehow to the ancient Greek idea of phlegm or pituita passing from the pituitary through the cribiform plate into the nasal cavity.¹¹(p1) Lastly, many victims during the Russian Campaign had both frostbite and hypothermia. These 2 conditions have been medically and historically intertwined, then and now.

Physical Science in the Napoleonic Era— Thermometers, Heat, and the Caloric Theory

Medical, physical, and environmental science was rapidly evolving in the early 19th century. As for cold, Beaupré recognized habituation or acclimatization. He wrote that the body reaches “a certain habitude of sensibility, which familiarizes with it the impression of

heat and cold.” He went on to illustrate different peoples molded by their climate but noted that within those groups “each individual is modified,” or *individual tolerance* as it is called today. He gives an example of the “indifference of Cretins to extremes of temperature.”⁸(pp16–21) Despite congenitally hypothyroid individuals having a myxedematous metabolic rate seemingly counterproductive for a cold setting, they were thought, if not actuarially known, to have longevity.¹² Today, divergent and controversial results exist between studies on cold adaptation in humans and other endotherms, but the main responses are either insulative (circulatory adjustments, changes in fat layers) or metabolic (shivering and/or nonshivering thermogenesis).¹³

Tolerance to cold temperature was important during the Russian Campaign. French scientist René Réaumur (1683–1757) constructed an ethanol thermometer on the principle of water freezing at 0° Ré and boiling at 80° Ré. Because of volume expansion of 8%, this was called *octagesimal*. Beaupré measured temperature that way, but the English translation used rounded Fahrenheit in the description of how soldiers tolerated degrees of cold. According to Beaupré, air temperatures were moderately cold down to 20°F (−7°C); rigorous for the French but not the hardier (or better prepared) Russians at even 10°F (−12°C); and excessively cold below that figure.⁸(pp13,16,30,34,149)

Actually, the temperature risk threshold is much higher. By the mid-20th century, there was better recognition of what “mild” cold could do. Physiologist Griffith Pugh analyzed reports of hill walkers who died in air temperatures as high as 50°F (10°C) when there were the added hazards of wind, wet, and fatigue.¹⁴ Beaupré had said much the same when he observed that the French Army’s problems began early with the cold rains of summer, long before winter. Both reported that dramatic mental and physical effects of unprotected exposure occurred in just an hour or two. Beaupré would even say that acute cold exposure could be so quickly fatal that “it acts like opium.”⁸(p150)

Multiple sources on the 1812 Russian Campaign were compiled into Charles Minard’s famous 1869 band graph, which is a cartographical depiction of data somewhat analogous to a pie chart. The band style later became erroneously called a Sankey flow diagram. Minard displayed 6 types of data: the number of Napoleon’s troops, coordinates, direction of travel, distance traveled, location relative to specific dates, and temperature nadir. He revealed temperatures as low as −30° Re,^{15,16} which is a very cold −37°C.

As for thermometers themselves, contemporary medical devices were large, slow, and not always well

calibrated. It was not until 1866 that a convenient 6-inch (15 cm), 5-minute clinical thermometer was devised by Englishman Thomas Allbutt. Measurements in the groin or axilla were the norm until later when the age of disinfectants made sharing an oral thermometer safer.¹⁷ Core body temperature was a developing concept. However, Beaupré's translator John Clendinning reported an interesting experiment on himself in the English translation book appendix. After 30 minutes in a 37°F (3°C) cold bath, he noted a drop in oral temperature of 3°F (2°C) and an axillary drop of 5°F (3°C), but that his urine was still 98°F (37°C).^{8(pp330–332)}

It would not be until 1945 that American Antarctic scientist Paul Siple would comprehensibly quantitate garment insulative value needed in dry cold and wind rather than just low temperature alone.¹⁸ His mathematical formula became known as *wind chill* or *wind-chill factor*, indicating not just clothing choice but frostbite risk. The clothing supplied for French soldiers, expecting a quick victory in 1812, was mostly summer uniforms. In particular, gloves and ear flaps were in short supply. Cold-incapacitated soldiers by the side of the road often had their clothes stolen when "Cossacks ill-treated them further by lance thrusts, or abandoning them, after stripping them of clothing, to all the rigours of cold." This theft may have been done by their own desperate colleagues: "More than one unfortunate was plundered before breathing his last sigh."^{8(pp109–115)} Much of this was a problem of logistics of clothing and food. Napoleon prepositioned material to last only weeks, not months. Beaupré criticizes his great leader on this point: "Above all, food must be properly secured: there lies the great talent of a general."^{8(p152)} A US Marine Corps commandant in 1980 emphasized that lesson: "Amateurs talk about tactics, but professionals study logistics."¹⁹

What temperature itself actually represented was still unknown. The older phlogiston theory of heat had only been recently replaced with Lavoisier's theory of heat called "the caloric." The caloric was a hypothetical substance whose presence in matter was thought to determine its thermal state. In Beaupré's words, it was "an elementary fluid, very subtle, invisible, imponderable, elastic and expansible, diffused though all nature, whose properties are known only by its effects."^{8(p3)} It would not be realized until later that heat and cold were not separate entities, but degrees of the same property.^{20(p1)}

With this ponderous thermodynamic hypothesis applied to biology, Beaupré first is bogged down trying to explain calorification: "Animal [or vital] heat is the result of the continual extrication of a certain proportion of caloric from the internal and external surfaces of all the organs." His discussion then improves: "Caloric ...

production seems owing ...to the decomposition or disoxygenation of the air in the lungs.... [and] The vital power of generating heat ...amounts to from 96 to 98 degrees of Fahrenheit."^{8(pp3–5)} This not only shows Beaupré's awareness of normal body temperature, but knowledge of Lavoisier's correct chemistry explanations that animal heat comes from the combustion of oxygen during cellular respiration.

Cold exposure was certainly felt in 1812, but how heat was moving in the body was unclear. Siple in his 1945 studies stated that cold sensations are related to the rate of heat exchange, not to tissue temperature alone, and reach their plateau in 3 to 20 seconds. Beaupré wrote that *dolor algidus*—the pain of cold—"is propagated along the course of the nerves."^{8(p14)} He may have been led astray by the caloric theory, yet he knew the effects of large quantities of iced drinks were not just local or in adjacent tissues but were disseminated all over the system, contracting tissues and concentrating blood toward the internal organs, describing well what today is called *peripheral vasoconstriction*.

All of these topics of physics, chemistry, and biology would have an effect on the treatment of frostbite and hypothermia.

Frostbite and Hypothermia Terminology in 1812

The terminology of frostbite and hypothermia in 1812 was archaic, used with bewildering overlap, and defined by Larrey, Beaupré, and an English medical dictionary of 1856.²¹

Asphyxia simply meant cessation of circulation. General asphyxia in the cold context of Larrey and Beaupré was the condition of a pulseless, unresponsive, severely hypothermic victim, with an effect that "extends at once over the whole machine."^{8(p141)} Only by the mid-19th century did general asphyxia or asphyxiation mean lack of oxygenation of blood from suffocation, submersion, or noxious gases or in newborns. In the 3 sources there is no mention of general asphyxia in cold being called hypothermia. That term came into use much later.

Partial asphyxia occurred in degrees, with local asphyxia defined as "the effect of cold on one point; what is vulgarly called frost-bite."^{8(p131–134)} The root cause was congelation, or congealing of fluids to solids. Beaupré made a finer distinction specifically for body fluids and blood: "In local asphyxia there is no proper congelation; the fluids are only coagulated in their respective canals."^{8(p50)} Today, micro- and macrocirculation damage is considered the main pathophysiological mechanism of frostbite; congelation in canals thus is not too far off the mark.²²

An asphyxiated limb could mean anything from early frostbite all the way to *sphacelus*, their term for late-

stage gangrene with poor chance of salvage.^{8(p131–134)} Sphacelus was often nuanced further to mortification, a dead body part. The etymology of gangrene derives from the Latin *gangraena*, meaning putrefaction.

Putrefaction was outright rot. Keeping a frozen body part cold, or only “warming it” with cold, would hopefully allow slow mummification, demarcation, and sloughing. On the contrary, warming a frozen body part risked loss not just the limb, but losing the whole patient from sepsis. This dreaded outcome highly influenced frostbite medical and surgical care.

Frostbite and Frostbite Treatment

Beaupré did allow warmth for treating cold-numbed areas of minor frostbite or mild hypothermia. However, for most cases, neither he nor Larrey followed the axiom *contraria contrariis medentur* (diseases are cured by remedies that are counter to them, such as treating cold with warmth).^{8(p135)} Instead, they recommended “cold on cold” for frostbite and even for hypothermia. Despite modern astonishment, some of their rationales were plausible.

First, thawing frozen fish or other food with only cold water to preserve texture, and reviving altogether different cold-blooded creatures, was mentioned by both authors. Everyday practices are powerfully persuasive, but they only state this briefly, not devoting whole chapters.

Second, cold frostbite was deemed to be like a hot burn injury, with Larrey stating, “Ulcers resulting from congelation generally present the same phenomena as burns.”^{4(p73)} Many soldiers’ numb feet were indeed placed too close to campfires, so there actually were some heat injuries. Perhaps this influenced him to treat frostbite’s injury with cold. Beaupré cited Hippocrates about the risk of putting hot water on cold feet.^{8(p136)} A good thermometer and quality control would have helped. Today, there are limits on how much heat is safe to apply.²²

Third, the bizarre caloric theory held sway. Beaupré himself was once so benumbed he could not use his own hands. This made him “neglect the wise precaution of friction with snow” to transfer the mysterious caloric factor from the cold to the cold body part and restore its vitality.^{8(p134)} Larrey says it this way: “It is necessary to rub the affected part with substances containing very little caloric, but which may absorb a good deal at the moment of their melting, and transmit it to the frozen part by rubbing.”^{4(p84)} If cold rubbing with or without various balms, stimulants, or snow failed, Larrey recommended that “the part ought to be plunged in cold water.”^{4(p85)} Somehow this backwards idea

persisted for a century or more. In 1945, wind chill expert Siple graphically reminded his readers of the fallacy: “The process of rubbing snow against a container holding liquid is the way ice cream is manufactured.”^{18(p230)}

Lastly, the *outcomes* reason for “cold on cold” rather than “heat on cold” for frostbite was the overwhelming fear of gangrene. Larrey states outright: “For it is well known, that the effect of caloric on an organized part, which is almost deprived of life, is marked by an acceleration of fermentation and putrefaction.”^{4(p85)} Beaupré said the same: “Heat is unsuitable; its imprudent application would be sufficient to cause rapid gangrene.”^{8(p135)}

They did do some watchful waiting, Beaupré hoping that, “nature marks out, sooner or later, a boundary between the dead and living parts.”^{8(p141)} With gangrene lurking, Larrey advised proximal amputation “above the seat of disease. Nature alone cannot separate parts labouring under necrosis.”^{4(p74)} They practiced the motto, “to cut is to cure,” and hoped for the best postoperatively. Today, advanced imaging helps guide these decisions.

Hypothermia and Dull Brains in 1812

Larrey himself stated that his brain was dulled by cold, writing that, “We were, in short, in such a state of faintness and torpor, that we were scarcely able to recognize each other.”^{4(p68)} He depicted others who “staggered, like men under the influence of intoxicating liquors...A painful numbness soon seized upon them, and lethargic drowsiness supervening, their sad existence was soon terminated.”^{4(p83)} Hypothermia, illness, malnutrition, exhaustion, and other factors all took their toll.

Another factor was alcohol. Both Larrey and Beaupré observed numerous examples of men under the influence of alcohol. It may have been the result of acute alcohol intoxication alone, for example, when a cannoneer drank an entire bottle of brandy in one long swig and died. In another incident, 800 soldiers pillaged a liquor storehouse, slept on the snow, and all perished. How much of this was drink, cold, or bad behavioral choices regarding shelter or clothing is unknown, but the vasodilatory risk of alcohol in cold weather was not scientifically understood until much later and is not universally respected even to this day.

Beaupré sadly witnessed that even those reaching camps did not always fare any better. He narrates the extent of the catastrophe: “The first hours of sleep offered...deceptive delight, precursor to the grave that yawned for them. Far from finding safety in the sweets

of sleep, they were seized and benumbed by cold, and never saw daylight more...Along the road, in the neighboring ditches and fields, were perceived human carcasses heaped up and lying at random in fives, then fifteens, and twenties, of such as had perished during the night."^{8(p113)}

Even makeshift hospitals, or asylums of humanity to Beaupré, were no safe havens. The sick and cold arrived only to lie "on the ground rather dead than living, and in that state expired."^{8(p119)} When patients' death was imminent, he saw their progressive cooling and mental lethargy. He accurately disclosed in great detail the signs and symptoms of general asphyxia, what today is called hypothermia.

Dulled mentation often explains the apathy of hypothermic victims found dazed and still, whether they be soldiers in 1812, cold hunters in the woods at sea level, or climbers near the top of Everest suffering from varying degrees and proportions of hypoxia, altitude-deterioration, hypothermia, frostbite, exhaustion, or all of the above. Unexpected recoveries do happen, as Beaupré reports, for despite "the image of perfect death...persons found senseless and deeply benumbed have been recalled to life after twenty-four or forty-eight hours."^{8(p141)} A modern example of such a seemingly miraculous recovery was the well-known saga of Beck Weathers in the 1996 Everest disaster.^{23,24}

Hypothermia Treatment with Activity

Beaupré warned of slower heat production with inactivity and gave advice to be like the masters of the cold north such as the Russians: "Constant and forced motion is necessary for the foot soldier, to save him from surprise."^{8(p152)} By surprise, he meant not the sword, but cold. He revealed his knowledge of far-off places and medical events such as Dutch whalers in cold Spitsbergen: "Those who took much exercise preserved their lives."^{8(p143)}

One of the great tragedies of accidental hypothermia occurs when victims appear at least superficially well, but then disaster suddenly strikes. For example, in Bob Marshall's *Alaska Wilderness*, sitting down was a fatal choice for a man traveling alone and unprepared in the cold. He stopped just 1 mile short of the next roadhouse, but "next morning they picked him up by the side of the trail in a sitting posture, frozen stiff. Like so many others, he had only sat down to rest for a minute which became eternity."^{25(p59)} Sometimes intense cold is overwhelming; other times victims have exercised to exhaustion, and often their dull brains have made poor choices. Beaupré knew the end result: "Once fallen it was impossible for them...to rise again. The danger of

stopping had been universally observed."^{8(p124)} Similarly, a climber on Everest in 1996 summed up these mutually exclusive options: "The only way to keep warm was to keep moving. A devil's bargain, when rest and warmth became incompatible."^{26(p219)}

Hypothermia Warming Techniques in the Napoleonic Era

Sometimes, they did understand parts of the equation. Larrey had noticed that imbibed cold water or snow absorbed a "small portion of heat remaining in the viscera."^{4(p82)} However, in most of the 2 authors' writings, they still emphasized the flawed cold remedy for both frostbite and hypothermia.

Beaupré chronicled the full procedure, repeated here in detail, with italics added for emphasis: "We begin by placing the body asphyxiated [ie, hypothermic] in a place where there is no current of air, and whose temperature is a little above that of the atmosphere; it is quickly stripped of clothes, and laid on a mattress or horse-bed. Frictions with some exciting tincture are made, and warm clothes are subsequently applied. Afterwards we proceed to use of snow, iced water, and water successively less cold, *in the same order and degree as in local asphyxia* [ie, frostbite]."^{8(p147)} He said to treat hypothermia just like frostbite: cold on cold.

Afterdrop and Circumrescue Collapse

Afterdrop and circumrescue collapse have some commonality. Afterdrop was detected experimentally when British physician James Currie became interested in hypothermia after a December 1790 shipwreck.²⁷ With air and water temperatures of 30°F (−1°C) and 38°F (3°C), respectively, some victims were heard to be first incoherent, then silent after just hours, but ultimately the men stayed on the wreck and most survived. The 3 who died were more exposed to wind and rain than were the survivors. Currie commented that how each man fared seemed to have no premorbid predictability. He later tested subjects and himself in water immersion or by dripping with cold fresh or salt water. Sublingual temperatures fell as low as 83°F (28°C), and recovery was observed. A warm bottle placed on the abdomen worked better than sips of brandy. Interestingly, he noted that sometimes after removal from immersion into air with towels, or into warm water, there was a fall in temperature before it rose again. This was afterdrop.

Beaupré, in his discussion of treatment for general asphyxia (hypothermia), showed that he clinically observed and understood at some level the phenomena of afterdrop and circumrescue collapse. He warned to avoid too much warmth for a reason different than that

for local asphyxia (frostbite), where the previously discussed fear of gangrene was paramount. For hypothermia, he recommended the surprising treatment and caution: “The like holds of general as of local asphyxia; we must not, in avoiding the danger from cold, transport the body into a heated place, or immediately apply to it warm substances; too strong re-action might exhaust the remaining vitality; the dilatation of the tissues and rapid expansion of the forces towards the surface, owing to sudden transition from cold and condensed to warm and rarefied air, causing shooting pains, dyspnea, suffocation, and death.”^{8(pp142,143)}

Beaupré seemed to be on the right track about afterdrop and circumrescue collapse. Today, afterdrop is attributed to continued core cooling during and after removal from cold exposure with conductive heat loss from the warmer core to cooler peripheral tissue and especially convective heat transfer from blood flow out to cooler tissues and subsequent return to the central circulation. The convective component is more affected by the method of rewarming and rescue movement.²⁸ A sudden insult of additional core cooling may precipitate cardiovascular instability with hypotension or ventricular fibrillation leading to syncope or sudden death. The term for this is circumrescue collapse. It may be aggravated by relative hypovolemia or loss of hydrostatic pressure on removal from cold immersion but also occurs in terrestrial rescue situations.²⁸ Today, like Beaupré advised in 1812, caution must be taken as to who, how, and when victims should be ambulated or carried to avoid circumrescue collapse.^{14,29,30}

Those in 1812 who were still ambulatory suffered the risk of circumrescue collapse. Both Larrey and Beaupré gave examples of soldiers who arrived to sudden warmth at fires, became inactive, and then dropped dead,^{4(p84),8(pp113,143)} likely because of afterdrop and/or circumrescue collapse from vasodilatation on application of sudden external warmth, or loss of internal heat production on stoppage of exercise, arrhythmia, lower catecholamines upon relief, or all of these factors.

Warm and Dead

Some resuscitated accidental hypothermia patients have survived with normal neurologic function even after cardiac arrest. Many of the usual indicators of death, such as fixed, dilated pupils and apparent rigor mortis are unreliable in severely hypothermic patients. A well-known caveat says it best, exemplified by a Norwegian author who began the title of his article with these familiar words: “Nobody is dead until warm and dead.”³¹ In that 28-year series, a patient who had a record-setting core body temperature of 13.7°C required

nearly 7 hours of resuscitation before spontaneous circulation was restored.³²

Beaupré also wrote that signs of death were misleading and not to give up: “Notwithstanding the greatest probability of ill-success, we must always afford the assistance.” However, without modern technology he had to rely on a more basic observation that nothing was certain “until after the appearance of signs of general putrefaction.”^{8(pp143–146)} In 1812, he saw plenty of that.

Conclusion

In their own way and time, early scientists and physicians learned about living or dying with frostbite and hypothermia. Modern medicine has a much better but still-evolving understanding of the body at cold temperature. The misery portrayed in the early 19th century accounts and descriptions that have been included in this essay helps to relate a unique and evocative story, both in terms of the wilderness literature and in illustration of some of the cold illnesses and physiology.

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