

St Kilda, the neonatal tetanus tragedy of the nineteenth century and some twenty-first century answers

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ABSTRACT Neonatal tetanus was the cause of death of two thirds of newborn babies on the archipelago of St Kilda in the Outer Hebrides for at least 150 years. This was a major factor in the community becoming non-viable. While the cause of the tetanus infections has never been clearly established, modern bacteriological evidence suggests an alternative source of infection to the previously established theory.

KEYWORDS Fulmar, handover, human error, neonatal tetanus, St Kilda, umbilical cord

LIST OF ABBREVIATIONS Glycine and gamma-aminobutyric acid (GABA), polymerase chain reaction (PCR)

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St Kilda ... nurses in its bosom the memory of its infant dead. – George Gibson, 1926

Whatever he studies, the future observer of St Kilda will be haunted the rest of his life by the place, and tantalised by the impossibility of describing it to those who have not seen it. – James Fisher, 1947

Tetanus, a truly dreadful disease. – Martha Roper, 2007

EARLY HISTORY

The cliffs of St Kilda are very high and visible on clear days from Harris and North Uist in the Outer Hebrides, which have been occupied since 4000 BC according to archaeological evidence. It is not clear when the first settlers came to St Kilda, but evidence suggests that people were there from prehistoric times, exploiting the rich resources of the sea, growing crops and keeping animals.

Simple stone tools found on the main island, Hirta, suggest that Bronze Age travellers may have visited St Kilda from the Western Isles some 4,000 to 5,000 years ago. In the 1830s, the Rev. Neil Mackenzie found remains of very old burial cists in Village Bay.

Excavations in 1995 revealed a possible burial structure dating from the Bronze Age. In 1844, an earth house (souterrain), possibly a store associated with an Iron Age house dating from about 2,000 years ago, was discovered. It consists of a long passage, with shorter passages or cells branching off. The Rev. Kenneth Macaulay¹ recorded that



FIGURE 1 The archipelago of St Kilda, the remotest part of the British Isles, lies 41 miles (66 km) west of Benbecula in Scotland's Outer Hebrides. Today it is owned by the National Trust for Scotland and, as the most westerly point of the UK, is used for surveillance by the Ministry of Defence.

three early chapels and two incised stone crosses of early Christian style had been found. Norse occupation is confirmed by archaeological finds of brooches and steatite vessels, and by the continued use of Norse place names such as Oiseval – the east hill – and Ruaival – the red hill.

EARLY RECORDED DESCRIPTIONS AND VISITS BEFORE DOCUMENTED NEONATAL TETANUS

Hector Boece² included 'the description of the Ilis of Scotland' in his history textbook of 1540, *The Chronicle of Scotland*. He described Hirta as the last island of Albion, and noted the rocky crags with the dangers of attempting a landing even in good weather. He wrote:



FIGURE 2 Aerial view of Hirta and Village Bay.
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'In the month of Juny ane priest cumis out of y Lewis in ane bait to this Ile, and ministers the sacrament of baptism to all y bairnis that hes bene borne in the year afore.'

Significantly, there is no mention of frequent neonatal deaths.

Donald Monro³ travelled through many of the Scottish Islands in 1549, giving details in his book *Descriptions of the Western Isles of Scotland called Hybrides*. He noted that the sheep of Hirta were larger and taller than those of the mainland, and that the people were simple and 'scant learnt in ony Religion'. Monro observed that the visiting chaplain baptised the bairns in midsummer. He did not record any illness beyond them being 'deid drukin' from the 'mask of malt' donated by the steward, Mcclloyd of Haray (Harris). Perhaps his most pertinent comment was 'but the seas are stark and verie evill entering ony of the saids Iles'.

Martin Martin^{4,5} made a more significant visit in 1695. Martin's father, Donald, had fought in the Civil War under the Marquis of Montrose. Martin himself was born in Skye, spoke Gaelic as his mother tongue and graduated MA from Edinburgh in 1681 and MD from Leyden by 1710. He was well acquainted with Robert Sibbald PRCP Edin., who considered that Martin was 'the person most capable to serve the Royall Society in the accounts of what relateth to ye description of ys Isles'.

Martin set sail for St Kilda from Harris at 6pm on 29 May 1697 and arrived in Village Bay, Hirta, on the morning of 1 June, having narrowly survived a violent storm at sea. His experience was common; undoubtedly the adverse climate with limited access to the island, particularly in winter, had a major impact on all aspects of island life and health until the evacuation in 1930.

Martin spent three weeks on the island. He was a keen observer of all facets of life. He noted: 'They are not

infested with several diseases which are so predominant in the other parts of the world.' On 17 June he observed the marriage of 15 couples and described the baptism ceremony, though he does not make it clear that he actually witnessed the event. He noted the fidelity of married couples and the care taken to avoid close consanguinity. Consanguinity may, however, have been closer than suspected following the then-current 'religious' leadership of a predatory character known as Roderick. Seduction formed part of his 'instruction' of young women. Sixty-three pages of the current revised edition of Martin's book are devoted to the life of the inhabitants of St Kilda, yet, like Monro, nowhere does he mention a problem of high neonatal mortality.

The Rev. Alex Buchan⁶ was the resident minister on the island from 1705 for many years, but again made no mention of neonatal deaths in his 1727 description of St Kilda.

David Mallet's book of poetry,⁷ published in 1747, described the St Kildans:

'Man's happiest life; the soul serene and sound
From passion's rage, the body from disease.'

Mallet's source of information, and whether he visited the island, is not clear, but he was unaware of the tragedy of common death in infancy. Yet within 11 years of the publication of Mallet's poetry, neonatal tetanus was documented as killing more than half of the island's babies, a devastating disease in a small community, which was later recorded as delaying baptism. It is possible, therefore, that the problem did not develop until the mid-eighteenth century, though high neonatal death rates may have been so common as to be not worth mentioning. Tetanus has long been known as the scourge of parturient women, newborn babies and wounded soldiers. In the eighteenth century, one out of every six infants born at the Rotunda Hospital in Dublin died from neonatal tetanus. Morgan⁸ reports that the death rate from 'the trismus' was higher in the Westmann Islands off the west coast of Iceland than on St Kilda.

REPORTS OF THE EIGHT-DAY SICKNESS, OR NEONATAL TETANUS, ON ST KILDA

The Rev. Kenneth Macaulay,¹ minister of Ardnamurchan, made the first mention of *trismus nascentium* or *tetanus neonatorum* in 1764, after a visit to the island of St Kilda in 1758, 61 years after Martin's visit. Like Martin, he sailed in summer, departing from Harris on 6 June. The crossing lasted overnight and Macaulay experienced adverse weather, requiring the help of the islanders to get safely ashore. His book of 278 pages devotes less than one page to neonatal tetanus, quoted in full below. Macaulay gives no explanation for these deaths. He wrote:

'The St Kilda infants are peculiarly subject to an extraordinary kind of sickness; on the fourth, fifth or sixth night after their birth, many of them give up suckling; on the seventh day their gums are so clenched together that it is impossible to get anything down their throats; soon after this symptom appears, they are seized with convulsive fits, and after struggling against excessive torments, till their little strength is exhausted die generally on the eighth day. I have seen two of them expire after such agonies. It is surprising that Martin, who was himself bred to physic, and a person of unbounded curiosity, should have passed over in silence a circumstance so very striking, supposing that this very uncommon distemper had got any footing on Hirta in his time.'

Like Macaulay, we are left wondering if Martin could have missed this problem, or if midwifery practice had changed for the worse during those 61 years. This is undoubtedly one of the very strange aspects of this sad story. Certainly the population was largely illiterate at the time. Midwifery practice would have been handed down by word of mouth from one midwife to her successor, with the risk of omission or error. Even today we are all familiar with the failings of handover; perhaps a new midwife was not informed of the traditional importance of passing the knife through a flame before cutting the umbilical cord. In 1822 the Rev. John Macdonald,⁹ on a visit to St Kilda, was the first to note that many of the mothers also died in childbed 'for the want of proper persons to attend them'. No details of maternal deaths in the 1820s are available to us.

John Morgan⁸ MA, MB (Oxon), MRCP (Manchester), visited St Kilda in 1860 and published details of his visit in 1862. The resident missionary, the Rev. Neil Mackenzie, showed Morgan the details in the parochial Island Register, which he maintained for the period July 1830 to September 1840. Thirty-three of the recorded 64 deaths were attributed to the 'eight-day sickness'. Figures for the period 1846–56 were incomplete. In 1856, under the Elcho statute, St Kilda was formally constituted a registration district. Morgan subsequently obtained the Registration District details for the five years from 1856–61 when eight of 17 deaths were attributed to *trismus* (see Table 1).

The only infant seen by Morgan survived uneventfully or, as a perhaps disappointed Morgan wrote, 'showed no disposition to satisfy my curiosity'. He appears not to have been present at the birth. Morgan spoke to the midwife about the clinical features. He noted she had 30 years' experience and had lost 12 out of 14 of her own children to this condition. These details enable us to identify Betty Scott. Morgan records her description in detail as follows:

'At the time of birth, there was no appreciable physical inferiority on the part of those infants who

TABLE 1 Figures from the Island and District Registers (incomplete 1840–56)⁹

Date	Live births	No of deaths in 28 days	Neonatal mortality rate %
1830–39	61	35	57%
1840–49	5	–	–
1850–59	11	5	45%
1860–69	29	20	69%
1870–79	28	14	50%
1880–89	27	14	52%
1890–99	25	6	24%
1900–09	15	2	13%
1910–19	17	1	6%
1920–29	7	0	0%

were so prematurely and suddenly selected as a prey. They were all proper bairns, and so continued till about the fifth or sixth day. The mother's eye might then not infrequently observe on the part of her child a strange indisposition to take the breast.'

Following the development of tetanic spasms, the jaw was noted to fall. This was seen as an invariably fatal prognostic sign, with death occurring within 30 to 70 hours from the first symptom.

Morgan noted that neonatal lockjaw had been ascribed to mismanagement of the umbilical cord among other possibilities, but he felt the management of the umbilical cord on St Kilda appeared to be the current best practice. Infectious diseases at the time were often attributed to climatic or environmental problems. He ascribed the neonatal tetanus to indoor fires and the accumulation of soot. He erroneously expected the disease to become a ravage of the past, following the reconstruction of better-ventilated cottages in 1861.

Arthur Mitchell,¹⁰ deputy commissioner for lunacy for Scotland (the position was thought unnecessary and abolished in 1913), wrote about St Kilda in 1865. His information came second-hand from the visits to St Kilda of the factor, Mr McRaid, and of Captains Otter and Thomas RN. Mitchell was mainly interested in the relationship between lunacy and consanguinity, but found no evidence of this in St Kilda. He also noted the high infant death rate, 84 out of 125 or 67%, mostly from *trismus*. His figures for the Westmann Islands were just lower, at 64%. Mitchell wrote:

'I made most carefull enquiry as to the mode of dressing the umbilical cord, but I did not find anything so exceptional in this matter as to lead me to suppose that it was in any way connected with the disease.'

Mitchell, in common with the early nineteenth-century perceptions of infection, also thought this was an environmental problem, with the absence of a smoke hole in the cottages and the damp climate being important factors. He came tantalisingly close to the cause by incriminating the presence of cattle and cattle dung in the homes during winter. He wrote: 'It is a painful thing to see our fellow-country men inhabiting dwellings whose construction is so uncomplimentary to human intelligence.' Animal housing, also noted by Macaulay, became much less common from the 1860s onward on St Kilda, though neonatal tetanus continued for another two decades.

John Sands,¹¹ MP and journalist, visited St Kilda in 1875 and again in 1876. He observed and participated in the life of the islanders during the many months spent there. Sands visited the other islands of St Kilda and shared in their grief. He noted the frequency of neonatal tetanus and described the current speculations in three papers, which were initially presented to an audience and subsequently published in *Chamber's Journal of Popular Literature, Science and Art*:

'Doctors differ as to the cause: some say that it arises from the mothers living on sea-fowl; others to weakening of the blood from long continued intermarriage; some that an operation necessary at birth is not properly performed; others that the infant is smothered with peat-smoke; whilst some aver that the child is killed by improper feeding; and I am now inclined to believe that the last is the true reason. Comparatively few of the children born on the rock survive for more than a few days; they are seized with convulsions and lockjaw, and soon become exhausted.'

One wonders what operation was thought to be the problem. At this stage, putting fulmar oil on the umbilicus was not considered to be a possible cause.

George Seton¹² visited the archipelago on the ship *Dunara Castle* in 1877. Tetanus had by this stage become a well-known clinical diagnosis, though bacteriological findings were still nearly 20 years in the future. Seton had read and researched many sources of information now unavailable about earlier visits to St Kilda. He found no evidence of frequent neonatal deaths before the writings of Kenneth Macaulay. He supported the theory espoused by one frequent visitor, Admiral Otter RN, that the disease was caused by the adverse effect oily food from seabirds had on breast milk.

Seton analysed the combined figures of Mackenzie from 1830–46 and the first 20 years of registration from 1856–76. He found a total of 132 deaths, 76 in infants and 56 in adults. Tetanus or lockjaw was recorded as the cause of death in only two adults; both female, one aged 25 and

one aged 34. Of the 76 deaths in children, 46 were diagnosed as lockjaw and another 26 as cause unknown. Seton's analysis clearly establishes tetanus as a disease predominantly of the newborn.

Emily Macleod, a relative of the island's proprietor, suggested in 1877, without success, that the St Kilda women should go to Skye for some nursing and midwifery training. Macleod, at her own expense, procured a trained nurse for St Kilda. Thus Miss McAulay became the first professional nurse to reside on St Kilda. She was obliged to fight against the local customs and prejudices and eventually left because of her unpleasant experiences. However, no baby delivered by her, during a nine-year stay, died.

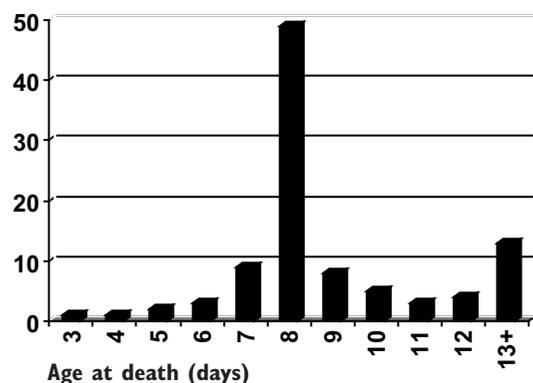
One hundred and twenty-eight years after Macaulay's visit, the tragedy was continuing unabated. The island's schoolteacher, George Murray,¹³ wrote in his diary on 12 December 1886:

'Last night at 10.30, after six days' intense suffering, the child departed this life. Every one expressed great wonder how it lived so long after being seized with the illness, as they generally succumb at the end of a week after they are born. This one was 13 days except one and a half hours. It had a frequent cry since it was born; but the first signs of its being dangerously ill was at the end of a week, when it ceased to suck the breast, but still sucked the bottle. The following day, the jaws fell (*thuit na gilan*), when all hope of its recovery were given up. From that time until its death it occasionally took a little milk in a spoon or out of a bottle. The last two days a little wine in water was given once or twice. It often yawned and sometimes looked hard at you. It was pitiful to see the poor little things in the pangs of death. May God prepare us all for the same end.'

When the child was buried, Murray wrote, showing significant insight in the last sentence:

'In the grave which was opened, I saw the coffins of its two little brothers that died in the same way. The one coffin was quite whole, there being only about 16 months since it was interred. On looking through the churchyard, I felt sad at the sight of so many infant graves. One man, not yet 50 years old, I should say, pointed to the place to me where he buried nine children. He is left with four of a family. Another buried no less than a dozen infants and is left with two now grown up. Sad to think of the like. Bad treatment at birth must have been the cause of so many dying.'

So general was this trouble on St Kilda that the mothers never thought of making any preparation for the coming baby. It was wrapped in a dirty piece of blanket till the ninth or tenth day, when, if the child survived, the affection

TABLE 2 Numbers of deaths on St Kilda, related to age in days 1840–1920¹⁹

of the mother asserted itself. The St Kildans appeared to accept these deaths, one stating: 'If it is God's will that babies die, nothing you can do will save them.' Some mothers endeavoured to avoid the problem by leaving in late pregnancy for their confinement in Harris. Donald McQueen, for example, between 1865 and 1875, lost five children and two wives, following childbirth, to tetanus. His third wife, Marion, had their second child on Harris in 1876, though this infant too died 12 days after birth. Marion had a further nine children on St Kilda, four of whom died within a week of birth.

LIGHT AT THE END OF THE TUNNEL

The Rev. Angus Fiddes, a Free Church clergyman and scientist, lived and worked on St Kilda in the last years of the nineteenth century. He was remarkable for his successful investigation into the cause of deaths of babies on the archipelago. In 1890, the year in which the tetanus toxoid was first purified, he applied to the Glasgow Sick Poor and Private Nursing Association for a nurse to assist on St Kilda. As a result of this, a second trained nurse, Miss Chisnall, went to St Kilda in 1890. She also experienced hostility, and some of the island women preferred the services of Mrs Fergus, the local midwife at the time. Fiddes wrote: 'They don't appreciate her services as they ought.'²¹

Fiddes and Chisnall went to Glasgow in an attempt to confirm the identity of the disease, its cause and remedy. Professor L Reid outlined current tetanus prophylaxis methods for Chisnall to use. The two deliveries she managed resulted in healthy babies, while the two she was prevented from supervising both died of neonatal tetanus. One other child born in this time was stillborn. Chisnall left in 1892 and no further resident nurse was found till 1914.

Fiddes then consulted Professor Turner,¹⁴ who advised breast-feeding of the baby from the first, the administration of one-grain doses of potassium bromide

at short intervals, covering the stump with a large pad of sublimated gamgee (antiseptic wool) and dusting with a small amount of iodoform powder. Turner said:

'This lax method of caring for the infant, the neglect to dress the cord, and the unsanitary condition of the dwellings, make it extremely probable that the infection was through the umbilical cord. All cases in which treatment was properly carried out by competent nurses have survived.'

Turner was also concerned that scissors used to cut a hole in the umbilical cloth should not be 'insanitary'. Fiddes encouraged improved sanitation, especially hand washing and clean baby clothes. In 1894, he reported to Turner that the last death from tetanus had been three years previously. The community was deeply grateful, and mothers began to bond with babies at birth. Fiddes retired in 1903.

SPECULATION

Apart from the theories espoused already, other suggestions were that the problem was birth trauma, delayed breast-feeding, intermarriage or lack of bathing of infants. Other St Kildan women delivered island babies; usually there were one or two nominated, but untrained, 'midwives'. Their delivery techniques were a closely guarded secret, never witnessed by a doctor or nurse. The process, including management of the umbilical cord, was discussed as noted above with two doctors, Morgan and Mitchell, who thought it sounded acceptable.

Sir Leslie Mackenzie headed an inquiry on South Uist in 1914 and was told that cord management had been little different on St Kilda from neighbouring areas. The management of the cord included encircling the stump with a rag through which a hole had been burnt. Gibson¹⁵ suggested, without definite evidence, that this rag may have been impregnated with fulmar oil, on the grounds that, in Lewis, the rag was smeared with salt butter in the eighteenth century. Macaulay stated that fulmar oil is one of the 'most efficacious ointments for healing wounds'. Macaulay continued with an unfortunate omission, 'besides a thousand other virtues of which he is possessed, which I have not time to enumerate'.

Gibson, a Fellow of the Edinburgh College of Physicians, did not quote Macaulay but otherwise displayed his literary erudition with a theatrical style. (As an aside, positioning his reader in a historical context, Gibson noted that Zachary Macaulay, a relative of Kenneth's and a war-profiteer, sold provisions to Spanish troops heading for the abortive Glenshiel rising.)

Following a brief visit and review of the records, Gibson described the archipelago as one of the 'waste and desolate places of the earth', which 'nurses in its bosom the memory



FIGURE 3 A fulmar in full flight. Fulmar oil may have been used in cord management on St Kilda. © Arthur Grosset

of its infant dead'. He noted the role of three ministers in the tetanus story: Macaulay who made the first description, Mackenzie who kept the first records and Fiddes who initiated the prevention of tetanus.

Gibson quoted Seton's data, stating that only two adult deaths from tetanus were recorded between 1856 and 1876 (in 1863 and 1867). Both of these were women. While the cause of maternal death was not always clearly recorded, correlation with the births and infant deaths in the register shows some of them died with their infant soon after delivery, probably both from tetanus. For example, Anna Gillies died on 4 June 1863 after giving birth to a boy who died of an unknown cause on 23 May, at the age of seven days. Tetanus was clearly rare other than in childbirth, indicating that the problem related to the umbilical cord.

Subsequently, with little evidence that it was used or was harmful beyond Gibson's evidence-free hypothesis, fulmar oil has been perceived as the culprit for many years. Apparently the babies were not washed or changed for five days after being trussed up tightly in clothes at birth. Alternative causes for the neonatal deaths have been suggested. The soils in the arable area on the archipelago have been found to be contaminated with heavy metals from the habit of ploughing bird carcasses back into the soil. In addition, the burning of chlorine-rich peat in home fires generates dioxin: these poisonous ashes were also added to the land, believing the fertility would be improved. However, had the deaths been due to toxicity, the babies would have had birth deformities and not have been 'proper bairns', the degree of illness would have been dose-related rather than the 100% death rate described, illness would not have been confined almost exclusively to neonates and postpartum mothers and other manifestations would have occurred beyond the typical clinical picture of tetanus.

Articles appeared in Scottish books and medical journals¹⁶⁻²² up to 1986 giving known details and possible causes of neonatal deaths. Some of these articles suggest

that fulmar oil may have been used to dress the umbilical cord. The oil was stored in gannets' stomachs, which may not have ever been cleaned. The result was that fulmar oil became firmly incriminated as the source of infection with tetanus.

The 75th anniversary of the evacuation of St Kilda was marked in August 2005 with an international conference organised by the Islands Book Trust and held in the Community Centre of Great Bernera. More than 100 delegates attended – mostly from the UK, but also a small number of international visitors, the latter including the author.

Estelin Walters, Emeritus Professor of Community Medicine at the University of Southampton, gave a comprehensive presentation on the health problems on St Kilda.²³ There were several other medical problems with most unusual features on the archipelago, some relating to the lack of herd immunity. Walters' time as the army medical officer to St Kilda during his national service enhanced his knowledge and understanding of the topic. He noted that three doctors – Mitchell, Morgan and MacDonald²⁴ – all expressed an opinion that the management of the cord was normal by accepted contemporary standards, as described to them, but never observed by them. He noted Gibson's hypothesis that the cord was anointed with fulmar oil, but is unable to attribute the source of this idea, which remains therefore only a hypothesis. Walters wondered if the fulmar oil may have been stored in sheep's stomachs, a much more probable source of tetanus than gannets' stomachs.

The matter may have been laid to rest at this stage, as the answers would have been buried along with the women who performed deliveries. Medical interest apparently could progress no further and the source of infection with tetanus could have remained a mystery.

TETANUS – CURRENT PATHOLOGICAL DETAILS

Tetanus is a neurological disorder, characterised by increased muscle tone and spasms, that is caused by tetanospasmin, a powerful protein toxin produced by *Clostridium tetani*. Hippocrates described tetanus, but the cause was not recognised until 1884 and the toxin not purified until 1890. The toxoid (chemically inactivated toxin) was first prepared in 1924.

Clostridium Tetani is an anaerobic, motile, gram-positive rod resembling a drumstick. The organism is found worldwide in soil, in the inanimate environment and in animal faeces. Spores may survive for years in some environments and are resistant to various disinfectants and to boiling for 20 minutes. Vegetative cells, however, are easily inactivated and are susceptible to several antibiotics (metronidazole, penicillin and others).

Tetanospasmin is formed in vegetative cells. The amino acid structures of the two most powerful toxins known, botulinum toxin and tetanus toxin, are partially homologous. Toxin released in the wound binds to peripheral motor neuron terminals, enters the axon and is transported to the nerve-cell body in the brainstem and spinal cord by retrograde intraneuronal transport. The toxin then migrates across the synapse to presynaptic terminals, where it blocks release of the inhibitory neurotransmitters GABA and glycine.

Neonatal tetanus usually occurs as the generalised form and is almost always fatal if left untreated. It develops in children born to inadequately immunised mothers, frequently after unsterile treatment of the umbilical cord stump. Its onset generally comes during the first two weeks of life. Poor feeding, rigidity and spasms are typical features of neonatal tetanus. The incubation period is a few days and mortality is high. The World Health Organisation reports annual deaths from tetanus in rural Third-World areas of more than 450,000 infants and 40,000 non-immunised postpartum women. The precise numbers are difficult to ascertain as only about 5% of cases are reported. Non-immunised mothers risk both their own and their child's life as vaccination protects both mother and child. The current introduction of health promotion programmes can reduce neonatal tetanus in Third-World countries.

There are parallels between the Maasai in sub-Saharan Africa today and the problems of St Kilda in the eighteenth and nineteenth centuries. The Maasai have traditionally applied cow dung to the umbilical cord to emphasise the importance of cattle to their lifestyle. Cow dung is not seen as offensive, and is used in ceremonies and to anoint the sick as well as a substitute for snowballs in children's games. Meegan²⁵ introduced a single-used returnable birth pack with sterile clamps, blade and threads with surgical spirit. This was presented by traditional carers between 1980 and 1999 with a recommendation to use clean water or milk, both culturally acceptable substitutes for dung. Neonatal deaths fell to 0.75 per 1,000 births, compared with death rates of 82 per 1,000 in non-intervention control communities or the pre-intervention period. The relative benefit of sterile equipment versus avoiding cow dung was not evaluated. Maternal and neonatal tetanus were the subject of a recent *Lancet* seminar by Roper.²⁶ While discussing neonatal tetanospsasms, she stated: 'Consciousness is preserved, making tetanus a truly terrible disease.'

TWENTY-FIRST CENTURY POSSIBLE ANSWERS

However, there is still one avenue of research that could clarify the problem. The possible sources of contamination with tetanus could be investigated in a modern pathology laboratory. A literature search did not detect any publications of such studies; hence I was delighted to learn from Morrice McCrae, the RCPE historian, that such research had been performed, presented at meetings and documentaries, though not yet published.

Ian Poxton, Professor of Medical Microbiology at the University of Edinburgh College of Medicine,²⁷ performed environmental studies on St Kilda in April 2004 at the request of Grampian TV. Soil samples collected from inside and outside the houses and storage cleits (small stone huts) were all found by culture and subsequent microscopy to contain *C. tetani*, and by PCR to be positive for the *C. tetani* neurotoxin gene. The Lothian Ringing Group collected fulmar oil or vomit from nesting birds in the Firth of Forth during the summer of 2004. All 40 samples were found negative by PCR for the *C. tetani* neurotoxin gene, and cultures did not detect any viable *C. tetani* organisms. A filter paper coated in fulmar oil placed in the centre of an agar plate inoculated with *C. tetani* did not inhibit growth of the organism, excluding antibacterial activity in fulmar oil.

The ubiquitous presence of *C. tetani* as a soil saprophyte in St Kilda has thus been confirmed. Samples from a greater depth may confirm the presence of *C. tetani* long before the arrival of Macaulay. The Firth of Forth fulmar has been found to be free of tetanus, and the same seems likely to be true for the St Kilda fulmars. The precise technique transferring the infection to neonates remains uncertain. Testing of the gannets' stomachs used to store fulmar oil would be interesting.

One aspect not previously considered in the St Kilda tragedy is the knife used to sever the umbilical cord. The sterility of the instrument used to cut the cord is now recognised by many authorities worldwide as the most important factor in the prevention of neonatal tetanus. Many cultures throughout the world have for generations sterilised blades by passage through a flame before severing the cord to prevent infection. Any knife used for other purposes on St Kilda would inevitably have been contaminated with tetanus spores. Alternative possibilities are the unclean 'swaddling' clothing used in the first week of life, and the cord ligature. Perhaps it is surprising that three doctors should describe unclean baby clothes as safe practice. We do not know what ligature was used for the cord stump. The St Kildans used horsehair to make ropes. If this was also used for ligating the cord, it could have been responsible for causing neonatal tetanus.

CONCLUSIONS

- Neonatal tetanus caused a high death rate on St Kilda for up to 200 years; the failure to replenish the population was a major factor in the failure of community.
- There is no clear explanation for the apparent absence of neonatal tetanus prior to Macaulay's observations.
- The precise flaw in the management of the umbilical cord remains unknown, but this must have been the route of infection.
- Appropriate sterile care of the umbilicus eradicated the disease.
- The tetanus bacterium was ubiquitous in the environment.
- There is no evidence that fulmar oil was used on the umbilical cord, and certainly no evidence that the oil is a source of infection.
- Pathological testing of the gannet stomach may be interesting. Even if negative, a frequently used but unclean container may well have been infected.
- The author believes the source of infection, as in many parts of the world, is more likely to have been the instrument used to sever the umbilical cord.
- Again, details of sterilisation will have been buried with the midwives. Perhaps the time has come to exonerate *Fulmarus glacialis* and appreciate that yet again human error and, perhaps, handover were responsible.

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