Medicine

A surgical dawn 31,000 years ago in Borneo

Charlotte Ann Roberts

Evidence that a child in a hunter-gatherer society survived amputation offers a remarkable insight into the origins of surgery. It challenges the current view that such procedures emerged alongside farming some 10,000 years ago. See p.547

The development of medicine was a key advance for early communities. On page 547, Maloney *et al.*[1] report skeletal evidence of the earliest known use of surgery — the successful complete amputation of the foot and partial removal of the lower leg (Fig. 1) of a child who lived at least 31,000 years ago in Borneo. This procedure occurred on the other side of the world and substantially earlier than the previous oldest known example of amputation, which was in France around 7,000 years ago[2].

Nowadays, dealing with illness and injury is for many across the globe intricately entwined with life itself, and caring for sick people is an inherent part of what it is to be human. In modern societies, people have created and developed complex infrastructure that promotes and enables the effective medical — including surgical — treatment of ailments.

Amputation is usually done safely in settings that provide good health care. Such surgery uses sterile procedures and general or spinal anaesthesia. The practice relies on doctors being able to: control the bleeding (or use blood transfusion to compensate for blood loss); manage pain; and, after the operation, prevent or treat an infection with antibiotics. Afterwards, rehabilitation is essential, and this might include physiotherapy, the provision of an artificial limb and emotional support. In some cases, people experience a 'phantom limb', which is a sense of pain at the site of the amputation, and many need support to adjust physically and emotionally to the loss of a body part.

Historical texts can tell us much about early medical therapies in communities that had developed written language, but direct evidence of such treatments from the bones of skeletons in a prehistoric archaeological setting is limited. Any disease or injury that affects only the skin or other tissues of the body does not necessarily leave traces in the bones, but might be found in preserved bodies such as Egyptian mummies. However, therapeutic measures to treat those ailments will usually not be detectable.

Figure 1 | Human remains with signs of amputation surgery 31,000 years ago. Maloney *et al.*[1] report the discovery in Borneo of evidence indicating that a person survived for between six to nine years after the amputation of their foot and part of their leg bone. This discovery provides a new perspective on when and where early surgery arose. Scale bar, 5 centimetres. (Image from Fig. 3 of ref. 1.)

Findings of treatments preserved in bones and teeth are mostly restricted to signs of dentistry, such as the presence of fillings, or surgical procedures, such as the removal of a piece of skull (termed trepanation) and amputations. There are also examples of copper plates found associated with infected regions of a skeleton, which are assumed to be evidence of previous medical care[3]. In the case of the amputation reported by Maloney and colleagues, and given the early time period, we do not have contemporary texts to support the practice of amputation in the region, unlike the situation in other contexts, such as an example from the eighth to fifth centuries BC in China[4].

Today, a body part might be amputated partially or completely if it is diseased, such as when a foot is affected by leprosy or a bone has a tumour, or if the tissue died because of poor blood circulation caused by, for example, an injury, frostbite or diabetes. Amputation can be used as a punishment, too, although that seems unlikely to have been the case for the skeleton reported by Maloney and colleagues. This is because the body was buried carefully and deliberately between six and nine years after the surgery, when the individual was 19 or 20 years old, and because microscopy evidence indicates signs of bone healing at the site of amputation.

That this child survived the procedure and is estimated to have lived for many years afterwards is astounding. The authors' careful study of the skeleton using information about current surgical practices, and by considering other options for the findings, reveals that this evidence is consistent with a surgical amputation. The leg bone shows a clean sloping cut rather than the more irregular physical hallmarks expected for an accidental injury that caused the loss of part of the limb. One can speculate about, but not prove, what type of sharp tool was used. Another interesting open question is whether the child received pain management during the operation, such as sedation through the use of a plant-based medicine.

The hunter-gatherer community in which this person lived would have been relatively mobile while foraging and hunting for food, and this would have made the individual's recovery process very challenging, considering how people recover from amputations and the need for care, rest, healing and rehabilitation. It could have been harder to support this child than someone in settled farming communities of later periods, where it would have been easier for people to help them at the same time as working in the community.

Maloney and colleagues' study is important because it provides us with a view of the implementation of care and treatment in the distant past. It adds to other research about community care in historical contexts, and, like other work[5], challenges the perception that provision of care was not a consideration in prehistoric times. That this person was given a deliberate burial in a cave when they died perhaps confirms that the care provided in life by this community continued after a person's death. Furthermore, there are signs of innovative behaviour in societies in this region of Borneo, namely, the creation of rock art 40,000 years ago[6].

One limitation to this type of research is what is described as the 'osteological paradox' — survival for a suitably long period after an illness or its treatment is necessary before traces (whether healed or not) can be identified in ancient bones[7]. Ancient amputations are much rarer than, for example, signs of osteoarthritis. However, a reason why amputations are not often identified in skeletons might be that no healing occurred (unlike in this case), perhaps indicating that the person died as a result of the surgery. This discovery in Borneo is from a prehistoric time period, so no complementary texts are available to tell us about what care or treatment was available and practised at the time. Nevertheless, the evidence does tell us that some level of care must have been provided by this community.

Although the bones are in good condition, the remains are of a buried skeleton rather than of a whole preserved body. This makes it more difficult to interpret what care might have been given. The discussion about what types of care would have been needed to keep this child alive has to be based on assumptions, because we can never prove what happened. Nevertheless, a 'bioarchaeology of care' might be developed in the future to address such issues for this case in Borneo. This approach includes a set of steps called the Index of Care[8] that can be used to assess whether a person with a disease or injury evident on their skeleton or in their soft tissues would need care to survive, and what might have been provided. It will be instructive to apply the index to this skeleton to gain a nuanced view of the specifics of the actual care that might have been necessary in this scenario.

What more could be studied? Taking a cross-section of the bone at the site of amputation and looking at it under a microscope would make it possible to identify diagnostic signs related to the healing of the bone using histological analysis[9]. Of course, healing can take place at different rates depending on aspects of a person's lifestyle (for example, malnourishment or infection might delay healing). This amputation is clearly well healed, and further microscopy would probably confirm the findings reported by Maloney and colleagues indicating that the amputation site healed well into what is called a resting state, and that the person survived for several years. This is a unique and ancient skeleton, and ethical considerations must apply to any analysis that would destroy bone in the process. Indeed, the information that might be gained would not add much to the story.

The authors also observed a mix of male and female features in the skull and pelvis, and were therefore not able to estimate the sex of the individual. The sex of the child might have had implications for their treatment. Taking a bone sample to try to analyse ancient DNA might provide some clues to genetic aspects of the various factors that underlie biological sex, but we do not know whether any DNA is preserved, and it would again be a destructive analysis of a rare find.

A lot of anatomical and physiological knowledge is needed for surgery, and this was often gained through the butchering and dissection of animals in early societies where the dissection of human bodies might not have been an option. However, for this person in Borneo, we cannot know for certain whether the surgeon had that type of knowledge, or whether they had any insights into how to prevent blood loss or infection. Nevertheless, amputating part of the limb, including the foot, would have been no small undertaking, and it raises the question of how bleeding was controlled during and after the operation. Perhaps plant material, such as sphagnum moss, was used. We certainly have evidence of past and present communities using the medicinal and physical properties of natural resources to treat ailments, and it would have been essential for healing that the wound was kept clean after surgery to prevent infection.

There is no evidence of infection of the remaining part of the left leg. The amputation is well healed, suggesting that if there had been an associated post-operative infection it was resolved. Of course, today a surgery-associated infection might be treated with antibiotics, but this treatment option would have been unavailable for the child if they needed treatment for infection.

Finally, whether the child had the use of an 'artificial limb' or a support (such as a crutch) could be contemplated. This has been considered for a sixth-century Austrian male individual who was excavated, although, in that case, there was archaeological evidence of an artificial foot preserved in the grave[10].

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Physical chemistry

Engineered molecules solve fluorescence issues

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The process by which pixels fluoresce in electronic displays uses energy highly inefficiently. The identification of fluorescent molecules with an unusual order of excited states opens up a fresh approach to tackling this issue. **See p.502**

Are you reading this News & Views article on a mobile phone? Do you stream your favourite series on a bright, flat-screen television, or help your kids do schoolwork on their tablets? If so, then one day you might benefit from the advance reported by Aizawa *et al.*[1] on page 502. They describe a breakthrough that overcomes long-standing constraints imposed by the laws of quantum mechanics on the energy efficiency of electronic displays, using a new strategy for understanding and engineering the interactions of light with matter.

When you flip a coin, the statistical probability of achieving either heads or tails is 50% when averaged over many trials, but the distribution of outcomes can vary for a small number of flips. Things are very different in the molecular world, because of the rules of quantum mechanics. Consider the physical process that produces fluorescence: an energy input puts a molecule into either a 'heads' or a 'tails' state (known as singlet and triplet states, respectively), with each state corresponding to a different energy of the molecule (Fig. 1a).