A Medieval (?) bone with a copper plate support, indicating an open surgical treatment

DAN-AXEL HALLBÄCK

OSSA

About 1928 a human humerus *sin.* of probable Medieval date was found during archaeological excavations at the Cistercian abbey of Varnhem, Sweden. The bone shows many pathologic changes, among others a proliferative bone reaction with two exostoses. These fit well with a copper plate, which has been wrapped around the bone in vivo, and held together with three rivets, sinews or threads etc., which now have disappeared. It seems likely that the patient had been the subject of some surgical treatment during which the copper plate had been applied. Judging from the bone the patient had survived this operation long enough for his lesion to heal.

The bone and the copper plate are described in some detail. The treatment as well as the reason for it are discussed.

Около 1928 года, в течение археологических раскопок в цистерцианском аббатстве в Варнхем (Швеция), была найдена, по всей вероятности, средневековая человеческая правая плечевая кость. На кости обнаружены патологические изменения, среди прочих – пролиферативная костная деформация, результирующаяся двумя выростами. Это отвечает попытке лечения такого заболевания с помощью медной пластинки, стянутой вокруг кости in vivo и скрепленной тремя заклёпками, сухожилиями или нитями, исчезнувшими к настоящему времени. Кажется вероятным, что пациент явился объектом какого-то хирургического вмешательства, во время которого была применена медная пластинка. Судя по кости, пациент прожил после операции достаточно долгое время, позволившее заживление повреждения. Дано детальное описание кости и медной пластинки. Обсуждаются способ лечения и его причины.

Dan-Axel Hallbäck, Institute of Physiology, University of Göteborg, Fack, S-400 33 Göteborg 33, Sweden

Vol. 3/4, pp 63–82, Lund. ISSN 0345–8865.

Introduction

In connection with the archaeological excavations of the Cistercian abbey at Varnhem, Västergötland, Sweden, 1923 to 1927 under the leadership of the late professor and King's Custodian of Antiquities S. Curman, and the late architect A. Forssén, a remarkable discovery was made in about 1928. In the so called aisle, i.e. not the one in the church, but the one in the cloister, a piece of human humerus sin. was found, which shows traces of advanced surgical treatments, primarily in the form of a copper plate, which had been wrapped around the bone in vivo, probably for stabilization.

This find met with little interest, and in the ATA-archives of the Museum of

History in Stockholm it is not possible to find any record of the number (18393:1090 Vg) on the bone. Upon request, the museum staff say that they take it, that the bone was found when the excavations were concluded and/or that the numbering was carried out indoors and subsequent to the excavation work. However, at this museum there is an investigation supplement, containing the following description: "Humerus from man with a copper plate support, length 23 cm, width 2.7-6.7 cm. Length of the plate 7.55 cm, thickness 0.15 cm. The bone shows well defined pathological changes. The plate that has rounded edges has been held together with three rivets, now disappeared. The north part of the aisle, 1928."

A newspaper article in the Göteborgs-Tidningen of August 12, 1928, mentions this bone, and reports that the bone was examined by the late professor Fürst of Lund, but to my knowledge, professor Fürst unfortunately has not left any written report of the examination.

Since 1928, the bone from Varnhem has been mentioned in at least four papers (W. Holmqvist, S. Bengtsson, S-A. Hallbäck and S. Lindroth). In these articles the bone is mentioned briefly and only as an example of Medieval surgical skill. It thus seems to me that this bone has been paid so little scientific attention that this article is justified.

Determination of age

An exact date would of course be of great interest, but, unfortunately, the C-14 method can only supply an inexact estimation within the actual time interval. Besides, the bone would have to be milled, and thus destroyed (Gejvall 1.). Another technique, the mass-spectrometry technique does not separate the minimal ^{14}C fraction from the ^{12}C and ^{13}C-ones, and so has not been used.

Neither can archaeology give us a reliable fixed time, as appears from the following short historical resumé. The facts in this resumé are mainly from A. Forssén and from F.A. Wingborg.

Varnhem abbey was founded in about 1150 by monks from Alvastra, Östergötland, Sweden. In 1234 a disastrous fire burned down the abbey, but restoration work was initiated immediately and lasted till about 1260. The present church dates from the last third of the 13th century. From the end of the 13th century and to 1527 the abbey flourished and grew in importance, both locally and nationally.

In 1527 king Gustav Vasa introduced the Reformation in Sweden, and the property of the abbey was confiscated by the State. The church and abbey fell into decay until 1566, when they were burned down by the Danes, and became ruins.

In about 1650 these ruins were visited by the wealthy count Magnus Gabriel De la Gardie, who decided to restore the church. The restoration started in 1654 and ended in 1674. As a result, the church got its system of large buttresses, which divided the north aisle into smaller parts. During the restoration of the church, huge masses of soil were transported from the vicinity to the former abbey, and the ruins were covered with a hill, which remained until the excavations 1923.

The Varnhem church, however, was more or less the private church of Magnus Gabriel De la Gardie and the nobility.

In 1695 the church was transformed into a parish church with public cemetery in accordance with a letter from the king dated February 23, 1695 (F. A. Wingborg, p. 27). Before 1695, the parish church was situated at Skarke about 1 km north of the Varnhem church.

Burials have thus taken place at the Varnhem church during three periods:

1. From the end of the 12th century to 1527.
2. From 1674 to 1695 (only the nobility and mainly in the interior of the church).
3. After 1695.

From my point of view, it seems likely that the bone was buried sometime during the period c. 1150-1527, probably after 1260, at or in the neighbourhood of the abbey of Varnhem. It is then quite possible that the bone, hidden in soil, has been moved during the restoration works in the 1650's/1660's.

That the bone was buried in the period 1674 to 1695 is a second possibility, but in view of the circumstances of the finding this seems less probable.

I can find no clues indicating that the bone was buried later than 1695.

Description

The relic consists of approximately 2/3 of the distal part of a left human humerus. The weight and measurements of the bone are shown in table 1. As can be seen in this table, the figures correspond comparatively well with those of the investigation supplement from the Museum of History, Stockholm. However, the figures of the bone length differ by 1.5 cm. The length of the bone can be

seen in fig. 1. Table 1 also contains the length and weight of the copper plate. Also in this case the figures correspond quite well, but the thickness of the plate is a bit too great in the investigation supplement.

The plate has the form of a rectangle with rounded corners. Each of the two short sides shows three holes, which correspond to those of the other side,

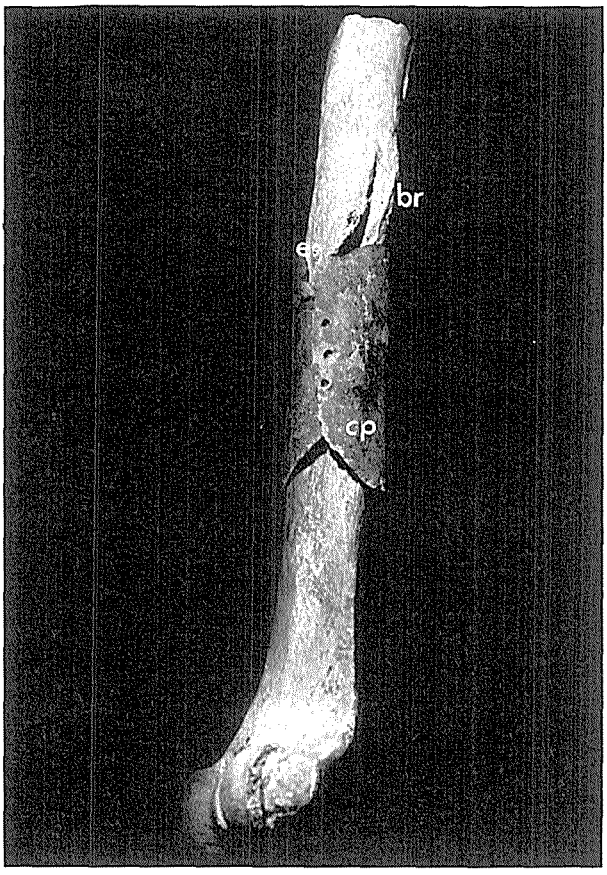
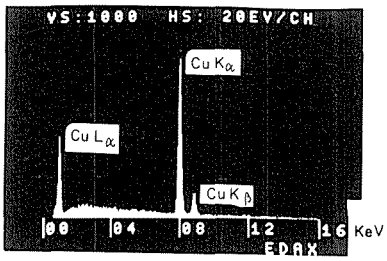


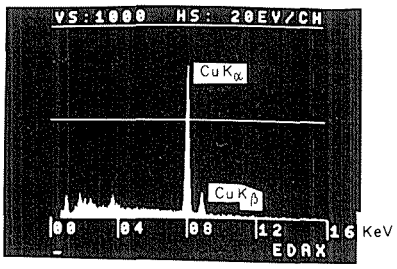
Figure 1. The bone from Varnhem, Sweden, seen from the lateral and ventral side. Note the proliferative bone reaction (br), with its two edges and central score. Note also the two exostoses (e), the copper plate (cp) and the verdigris (v).

PHOTOS OF SCREEN SCANNINGELECTRONMICROSCOPETECHNIQUE.

A. POLISHED PLATE



B. UNPOLISHED PLATE



DETAIL OF PLOT. FLUORECENCETECHNIQUE.

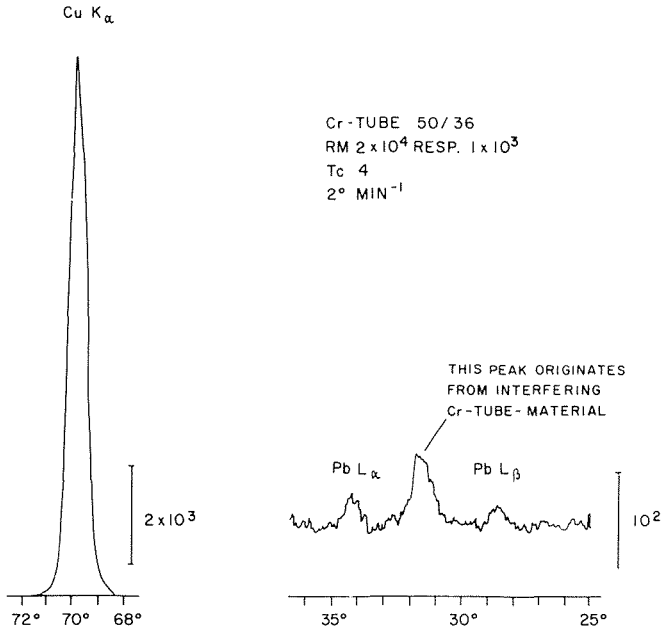


Figure 2. Chemical examinations of the copper plate.

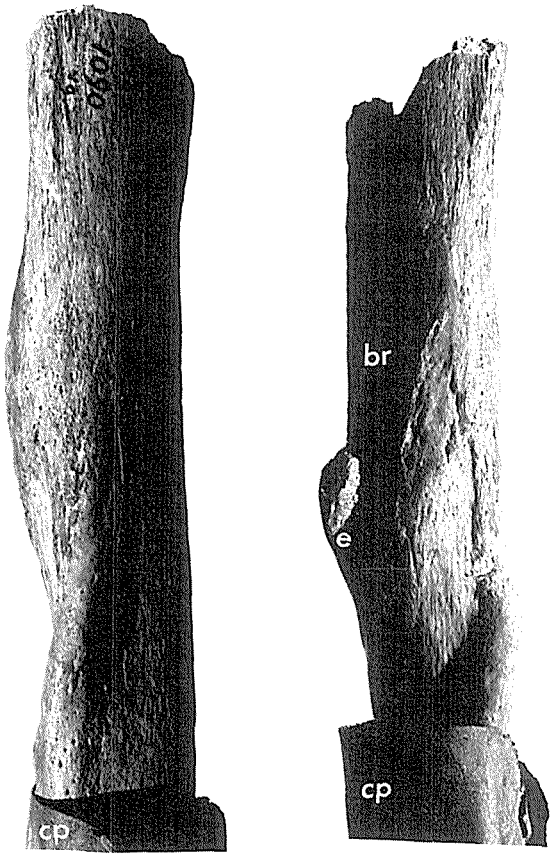


Figure 3. (left). Proximal part of the bone seen from the dorsal and medial side. Note the proliferative bone reaction (br) with its porous surface and the copper plate.

Figure 4. (right). Proximal part of the bone seen from the dorsal and lateral side. Note the larger of the two exostoses (e) and the proliferative bone reaction (br) with its porous surface. cp = copper plate.

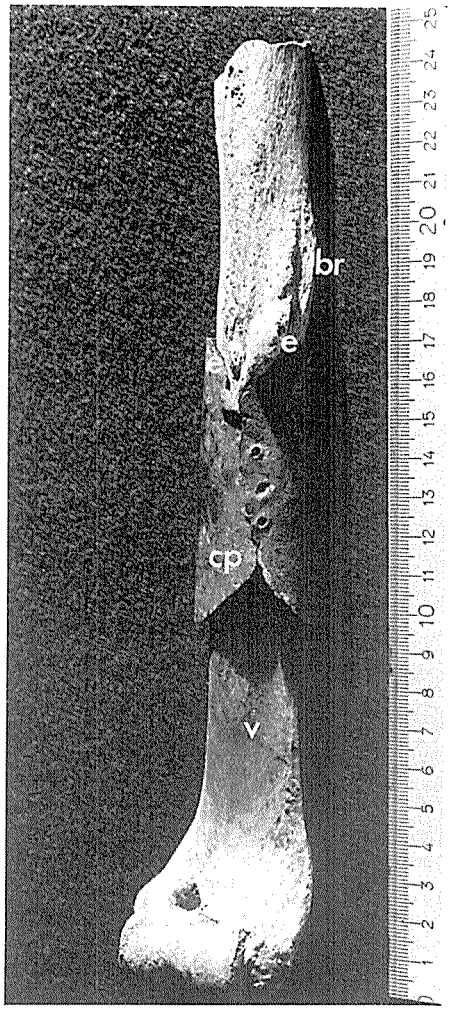


Figure 5. The bone seen from the lateral side. Note the two exostoses (e), the proliferative bone reaction (br) with its central score, the copper plate (cp) and the verdigris (v).

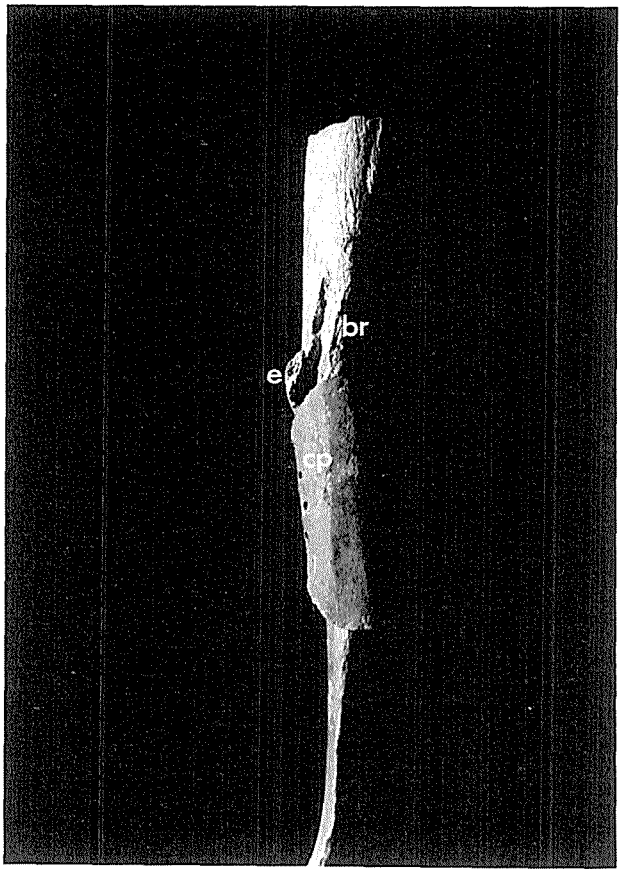


Figure 6. The bone seen from the lateral side. Note the larger of the two exostoses (e), the proliferative bone reaction (br) with its central score, and the copper plate (cp).

and probably have been held together with rivets, sinews or threads, nowadays disappeared. A second possibility is that there were three pins, used to nail the copper plate to the bone. The absence of holes or marks on the bone speaks against this theory. When the six holes are brought together to fit three to three,

the copper plate is held firmly to the bone, so that there is very little space left for soft parts under the plate. It is nevertheless possible to move the plate on the humerus between the distal epiphysis and an exostosis connected with a proliferative bone reaction in the proximal part of the remaining piece of bone. On the plate some smaller flaws are visible.

Analysis of the content of the plate gives evidence of a remarkably pure copper. Assuming that the sample is representative for the whole plate it thus consists of:

Cu	99%
Pb max	0.5%

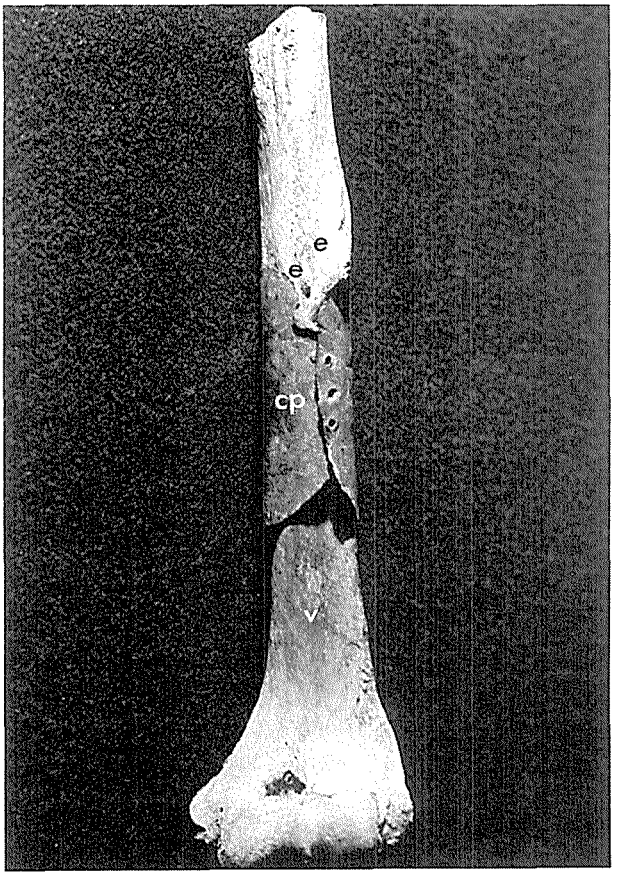


Figure 7. The bone seen from the ventral side. Note the two exostoses (e), the copper plate (cp) and the verdigris (v). Note also the little Foramen in Fossa coronoidea (not mentioned in the text).

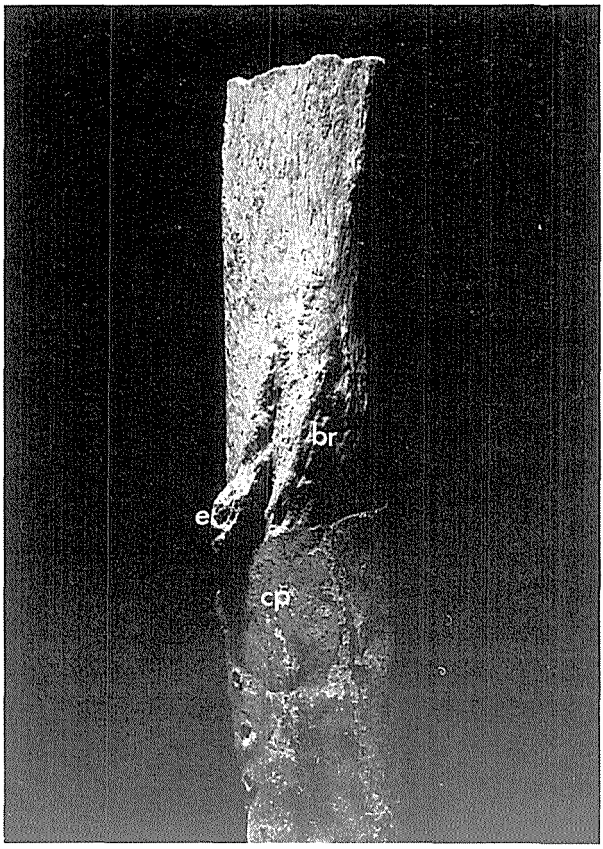
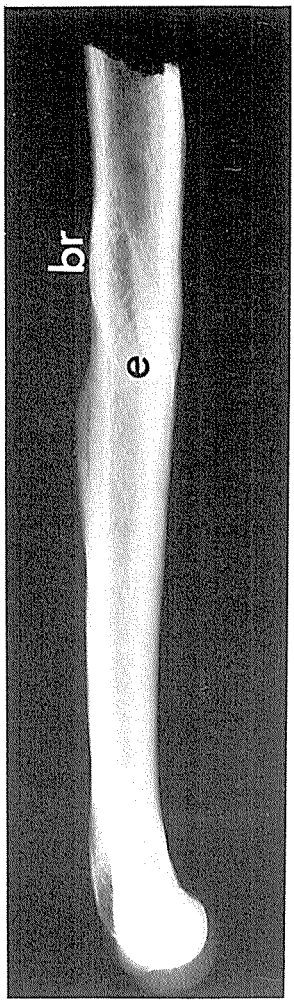


Figure 8. A close up picture of the proliferative bone reaction (br) with its two edges and central score. Note also the larger exostosis (e) and the copper plate (cp).

Proximally on the anterior face, approximately on the place where the distal part of the deltoid muscle is attached to the bone, a proliferative bone reaction can be seen. This bone reaction is approximately 6 cm long and 2 cm wide. It consists of two parallel edges with a score between them. The surface of the bone is porous, a defect which seems to originate from an inflammatory reaction.



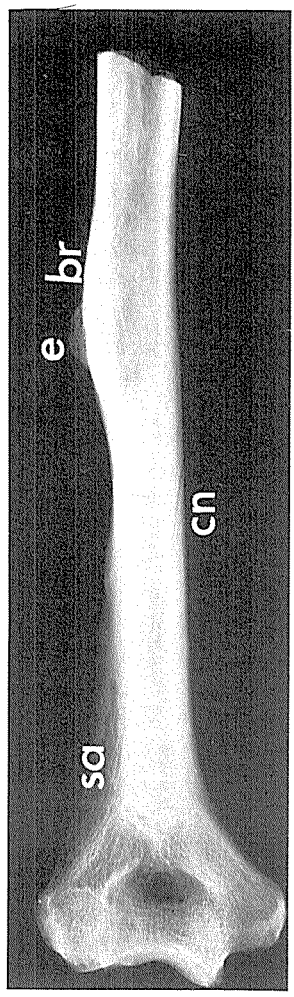


Figure 9. (left). X-ray picture. Side view. Note the proliferative bone reaction (br) and the larger exostosis (e), seen as an opaque ring.

Figure 10. (right). X-ray picture. Front view. Note the proliferative bone reaction (br) and the larger exostosis (e). Note also the spotted area (sa) and the Canalis nutricius (Cn) mentioned in the text.

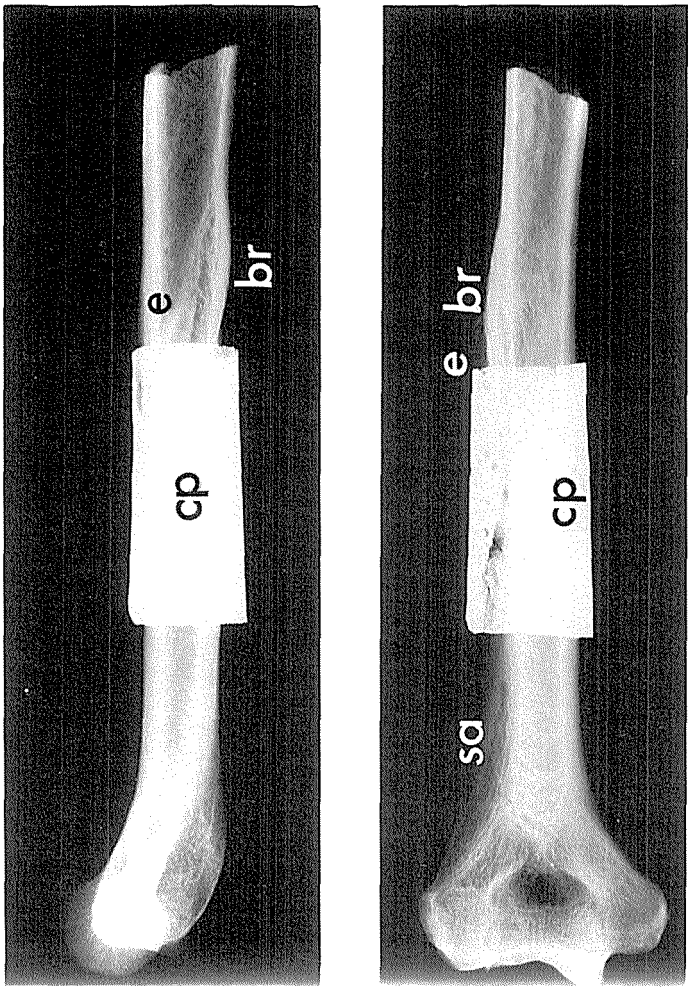


Figure 11. (left). X-ray picture. Side view with applicated copper plate (cp). Note the very distinct appearance of the proliferative bone reaction (br) with its central score. Note also the larger exostosis (e).

Figure 12. (right). X-ray picture. Front view with applicated copper plate (cp). Note the proliferative bone reaction (br), the larger exostosis (e) and the spotted area (sa).

The porous surface of the bone reaction can be seen in fig. 3 and 4. At the distal part of the anterior edge two exostoses can be identified (see fig. 5, 6, 7, and 8). The bigger, more laterally placed exostosis has a height of about 8 mm, a length of 2.5 cm and a width of 9 mm. The smaller and medially placed exostosis has a height of approximately 1.5 mm, a length of 6.5 mm and a width of 3.5 mm. On both exostoses the cortical layer is defective and the cancellous bone is visible. The bigger exostosis fits well in with the copper plate, as can be seen from fig. 1, 5 and 7. About two cm below the bone reaction, and situated on the lateral verge, an intact nutrient foramen with a diameter of 0.8 mm is visible. This foramen is thus to be found under the copper plate.

When compared with a normal humerus, neither rotation nor dislocation occurs. The shape of the bone seems fairly rough however, indicating that it originates from a man. The rough shape may also indicate pathology.

On corpus humeri, presumably on facies anterior lateralis and medialis, a marked verdigris is visible, which can be seen from fig. 1 and 7.

On the distal part of the bone some cortical defects with underlaying cancellous bone can be seen. The surfaces of the joint seem to be unaffected by diseases.

On the side view (fig. 9) an oblique structure is seen in the proximal part. In its ventral part, the structure is more opaque, and this part represents the proliferative bone reaction. Also the bigger exostosis is visible as an opaque ring.

On the dorsal side and distal to the bone reaction, the corticalis layer is much thicker than elsewhere, but this is an effect of the X-ray projection.

On the front view of the X-ray pictures (fig. 10), the proliferative bone reaction is quite distinct, and can be seen on the lateral side. The dense part of the reaction has a width which is twice the width of the corticalis proximal to the reaction. A central clearing in the bone reaction is visible. The bigger of the two exostoses is discernible. The corticalis defect, as well as the cancellous bone in the exostoses, can also be seen.

Distal from the bone reaction and on the medial side a sharp line in the corticalis is visible. This line probably originates from a Canalis nutricius. This assumption is supported by the fact that a Foramen nutricium can be found on the bone surface in agreement with the X-ray picture (see above).

On the distal part of the bone, and on the lateral side, a spotted area can be seen. This area may, in part, be due to the verdigris.

On both sides and in frontview the inner contour of the corticalis layer is smooth

and no fracture notch is discernible.

Discussion

According to the above mentioned newspaper article in Göteborgs-Tidningen of August 12, 1928, the cause of the operation is a fracture. It is also stated that the treatment was successful, but that the patient probably died rather soon. In addition to this newspaper article, the bone from Varnhem is also mentioned in four other works (W. Holmqvist, S. Bengtsson, S-A. Hallbäck and S. Lindroth). In the latter ones, the bone is only briefly mentioned as an example of Medieval surgical skill. W. Holmqvist suggests that the cause of the pathological changes is syphilis, which is reported in some skeletal remains from cloister in Denmark (Kr. Isager and E. Sjövall). An interesting remark of Holmqvist's runs as follows:

"... and the most remarkable is may be that this (= the copper plate[x]) has been, iron hard, fixed with threads, which, evidently, have been wound round the very bone, to leave the soft parts with their blood vessels free."

The question of what caused the pathological changes is indeed a very important one, and when examining the bone we have to consider at least four possibilities, which are listed below:

1. Neoplasm
2. Specific infections, preferably syphilis.
3. Unspecific infections
4. Fracture

There is no evidence of a neoplasm. It also seems unlikely that a tumour, leaving so relatively few marks on the morphology or on the X-ray pictures, should give such severe symtoms, as to justify this advanced method of treatment. When consulted, orthopaedic specialists also believe neoplasm to be a very unlikely alternative. Note, however, the spotted area on the distal part and on the medial side, which is probably due to the verdigris, but which somewhat resembles a pathological phenomenon.

Also a specific infection, such as TBC, syphilis etc., is an alternative of little probability, as there is nothing on the morphology showing bone destruction as in the case of TBC or showing the snail eaten appearance as in the case of syphilis (Robbins, Wells and others). The X-ray pictures cannot supply us with any indications of a specific infection, and consulted orthopaedists and the pathologists

x/ My remark and underlining.

also believe the alternative of a specific infection to be improbable.

Skeletal remains supposed to be syphilitic and with clear marks suggested to have come from bands which have been wound round the bone are presented by Kr. Isager and E. Sjövall, and found at the Øm monastery in Denmark. Their syphilitic character seem however doubtful in the view of the following circumstances (Gejvall 1 and 2):

1. The marks demands extensive syphilitic necrosis leaving the bone exposed. It is hard to believe that such a severe case of syphilis could survive long enough for the bandage to leave such traces of impressions as in this case.
2. The bands must have been passed in between the tibia and the fibula in some cases, which also seems highly unprobable.

Professor Gejvall offers a more probable explanation for these marks in his thesis about skeleton remains from Westerhus (Gejvall 2), where he describes a skeleton from Mjärthögen with similar marks (appendix). Note that in this case, the disease is not syphilis but eventually Mb Paget. According to professor Gejvall:

"the channellings must therefore be interpreted as greatly deepened sulcu arteriosi et venosi as a result of the mechanical effects of the progressive increase in size of the bony accretion." In his book professor Gejvall gives clear evidence for this theory.

Since syphilis did not begin to appear frequently in Europe until around 1500 (M. Bergmark), this gives us a very narrow time interval as far as the alternative of syphilis is concerned.

A third alternative is an unspecific infection, an osteomyelitis, a periostitis or an infection in the soft parts. The fixation of the plate so closely to the bone as in this case entails seriously damaged soft parts, and it is a true surgical exploit to carry through this operation so that the patient survived. On the other hand, we cannot exclude the possibility that the copper plate may have been put in to disinfect the wound, in much the same way as copper is now used as an asepticum in the odontological field.

L-I. Jönsson has written about the famous humerus (sin.) fracture of King Erik XIV (1533-1577) of Sweden. This fracture arose from an attempted assassination when the king was kept prisoner. The fracture healed, but within the healed fracture small pieces of iron are to be seen. There are two theories about these iron pieces; either they originate from the weapon (a gun), that caused the frac-

ture, or they have been placed in the wound in order to prevent an infection. This method of putting iron or copper in wounds in order to prevent or stop infections is known since antiquity (A. C. Celsus), and if the second theory is adopted, one may assume that this technique was known and practised during the last part of the Medieval period in Sweden. This royal arm lesion was first described by professor C-H. Hjortsjö.

Note also that the copper plate itself may have caused the bone reaction (chemically and/or mechanically).

The last alternative is that the copper plate was put round the bone to stabilize a fracture. According to the available literature, fractures have been accounted for in most societies and during most periods (among others: J. M. Allison et al., J. L. Angel, D. Brothwell, C. B. Courville, R. R. Crawford, N-G. Gejvall (3), M. S. Goldstein, S. P. F. Hughes, J. L. Price, J. G. Roney, H. E. Sigerist, C. Wells etc.). Most fractures described in this literature have been healed, often with more or less dislocation. The question is whether a well healed fracture with no or little dislocation is an indication of human skill in treatment, and splinting of fractures (Sigerist, Wells and others). Well healed fractures with very little dislocation do, however, occur among animals, for instance among apes (Schultz) and birds (Lepiksaar). On the other hand, treatment of fractures seems to have started at an early date according to G. E. Smith who has examined the art of splinting among old Egyptians of the V:th dynasty and according to Moulin who has written about treatment of facial fractures in Hippocrates' time. Open surgical treatment of fractures does not become more frequent until the 19th century but the techniques are rather well developed in the first part of the 20th century (A. Lambotte). Adopting the fracture alternative one may very well consider that the treatment of the above described bone from Varnhem is one of the oldest of its kind in history.

As pointed out neither dislocation nor rotation in the bone is to be found when compared with a healthy humerus. It has also been mentioned that there are no fracture notches on the X-ray pictures. The explanation may be as follows.
If the patient got his injury from, say, an axe or a sword, the result may have been a wound where the bone was bared and visible, more or less damaged. With these presumptions, it would have been natural for the monks who administered the treatment to try to stabilize the bone by placing the copper plate round it, a task that would be possible with the open wound. When the bone was stabilized,

the arm may have been bandaged. The copper in the plate must have had a strong antibacterial effect on the wound, and the infection risk was thus diminished, despite lack of sterile conditions.

An explanation as described above also sounds very plausible to orthopaedic specialists consulted. The lack of fracture notches on the X-ray pictures is a fair possibility in view of the fact that the patient survived for some years after the treatment. Nevertheless, this operation must have been a very difficult task, considering the lack of adequate narcosis and the very difficult surgical area of the fracture. It is surprising that a type of wound which probably was not unusual during the patient's lifetime just as it is fairly common today, was treated with the above described, unique surgical technique, but the circumstances may justify the assumption that the patient was quite an important person.

Another possibility is that the copper plate had been wrapped round the outside of the intact arm, and then gradually strangulated the arm. A fact that speaks against this theory is that the distal parts of the bone are not degenerated or in other ways affected, which could be expected. Furthermore, an intact Foramen nutricium can be seen under the copper plate as has been mentioned above.

Note also that after the death and burial of the patient, the copper plate has slid down to the distal epiphysis, where, for centuries, it has verdigrised the bone (fig. 1 and 7).

Conclusions

1. Sex

The weight and measures indicate that the bone originates from a male.

2. Age

This man probably lived and was treated for his injury within the period 1260-1527.

3. Pathological cause

The most probable cause for the treatment is a fracture caused by violence in some form. The alternative of an unspecific infection cannot be excluded. A neoplasm or a specific infection are alternatives of less probability.

4. Technique

My assumption is that the injury was caused by a cut from, for instance an axe or a sword, which led to an open wound, with the bared bone visible. The bone was probably not cut in two pieces. The plate was placed round the bone to bring about stabilization. At the same time, the pure copper had an antibacterial effect on the wound. Whether this effect was deliberate or not is impossible to say.

5. Survival

Judging from the bone, and considering the well developed exostoses and the proliferative bone reaction, as well as the lack of fracture notches on the X-ray pictures, the patient must have survived for years, may be decades. Note that nothing can be said about the function of the arm after the operation.

Acknowledgements

I want to express my gratitude to docent Jan Sandegård for supporting me with literature, constructive criticism, stimulating discussions and a never failing interest. I am much grateful to my father, Provincial Custodian of Antiquities S-A. Hallbäck, who showed the bone to me, and who has been of invaluable help to me, as far as archaeological and historical datas are concerned. I am also grateful to docent Bo Nilsson for much advice in matters concerning technical determination of age. To all others to whom I showed the bone, and with whom I discussed it, I also want to express sincere thanks for support, advice and constructive criticism.

For helping me with analyses of the copper plate I thank engineer Lars Eklund and engineer Åke Åkerström at the Swedish Silicate Research Institute, Chalmers Institute of Technology, Gothenburg. For helping me with taking the X-ray pictures I thank professor Sven Scheller and photografer Ole Roos. For helping me with drawing table 1 and picture 2 I thank Miss Pia Larsson and photographer Thomas Palm. For scrutinizing the English I thank Mrs Sara Arvidsson. For typing the final manuscript I thank Miss Elvy Wigholm.

Table 1.

The bone		
max. length	24,3	cm.
diameter of corpus Humeri	2,5 - 3,0	cm.
max. width of the distal epiphys of Humerus	6,9	cm.
weight	95,12	g.
The copper plate		
max. length	7,3	cm.
max. width	10,0	cm.
thickness	0,6 - 0,8	mm.
weight	17,26	g.

References

Allison, J.M., Mendoza, D. & Pezzia, A. 1974: A radiographic approach to childhood illness in precolumbian inhabitants of southern Peru. Am. J. Phys. Anthropol. 40, 409-416.

Angel, J. L. 1946: Skeletal change in ancient Greece. Am. J. Phys. Anthropol. 4, 69-97.

Bengtsson, S. 1975: I Västgötabygd. Skövde. (In Swedish).

Bergmark, M. 1965: Från pest till polio. Natur och Kultur, Stockholm. (In Swedish).

Brothwell, D. 1961: The palaeopathology of early British man. J. Roy. Anth. Inst. 91, 2, 318-343.

Celsus, A. C. 1906: Åtta böcker om läkekonsten. (Eight books of art of medicine.) Translated and annotated by M. V. Odenius. Gleerups, Lund. (In Swedish).

Courville, C. B. 1950: Cranial injuries in prehistoric man. Bull. Los Angeles Neurol. Soc. 15, 1-21.

Crawford, R. R. 1973: A history of the treatment of non-union of fractures in the 19th century, in the United States. J. Bone Joint. surg. am. 55, 1685-97.

Forssén, A. 1969: Varnhem. Kungliga Vitterhets- historie- och antikvitetsakademin. Svenska fornminnesplatser nr 8, 2nd ed. (In Swedish with English summary).

Gejvall, N.-G. (1): Osteological Research laboratory, University of Stockholm, Sweden. Personal communications.

Gejvall, N.-G. (2) 1960: Westerhus. Medieval population and church in the light of skeletal remains. Kungliga Vitterhets- historie- och antikvitetsakademin. Lund.

Gejvall, N.-G. (3) 1968: Patologiska fynd i ett medeltida material. Ronden 20, 231-234. (In Swedish).

Goldstein, M. S. 1969: The palaeopathology of human skeletal remains. In Brothwell, D., Higgs, E. & Clark, G. (eds.): Science in archaeology and research. Thames & Hudson. 2nd ed.
Göteborgs-Tidningen, August 12, 1928: Varnhems kloster utgrävt. (In Swedish).
Hallbäck, S.-A.: Museum of Västergötland. Skara. Personal communications.
Hallbäck, S.-A. & Ahlgren, J. 1976: I platåbergens landskap - en bok om Västergötland. Forum, Borås. (In Swedish).
Hjortsjö, C.-H. 1962: Erik XIV. En historisk, kulturhistorisk och medicinsk-antropologisk undersökning i samband med gravöppningen 1958 i Västerås domkyrka. C.-H. Hjortsjö (ed.), Norstedt, Stockholm. (In Swedish).
Holmqvist, W. 1947: Den stora döden. Svenska Turistföreningens årsskrift 1947, p. 106-121. (In Swedish).
Hughes, S. P. F. 1975: An historical review of fractures involving the ankle joint. Mayo. Clin. Proc. 50, 611-614.
Isager, Kr. & Sjövall, E. 1936: Skeletfundene ved Øm kloster. Levin & Munksgaard, Køpenhavn. (In Danish and Swedish).
Jönsson, L.-I. 1976: Mynten med Älvsborg. Erik XIV:s 3- och 1,5-mark 1562. Numismatiska litteratursällskapet i Göteborg, Göteborg. (In Swedish).
Lambotte, A. 1924: Chirurgie opératoire des Fractures. Bruxelles. (In French).
Lepiksaar, J.: Museum of Nature, Gothenburg, Sweden. Personal communications.
Lindroth, S. 1975: Svensk lärdomshistoria. Medeltiden - Reformationstiden. Norstedt, Stockholm. (In Swedish).
Moulin, D. de 1974: Treatment of facial fractures in Hippocrates time. Arch. chir. neerl. 26, 283-288.
Nilsson, B.: Department of medical chemistry. Univ. of Gothenburg, Sweden. Personal communications.
Nomina Anatomica 1966: Excerpta medica fondation. 3:d ed.
Price, J. L. 1975: The radiology of excavated saxon and Medieval human remains from Winchester. Clin. Radiol. 26, 363-370.
Robbins, S. L. 1967: Pathology. 3:d ed. Saunders.
Roney, J. G. 1959: Palaeopathology of a california archaeological site. Bull. Hist. Med. 33, 97-109.
Sandegård, J.: Department of orthopaedic surgery II, Sahlgren Hospital, Univ. of Gothenburg, Sweden. Personal communications.
Schultz, A. H. 1939: Notes on diseases and healed fractures of wild apes. Bull. Hist. Med. 7, 571-582.
Sigerist, H. E. 1951: A history of medicine. Vol. 1. Primitive and Archaic Medicine. New York.
Smith, G. E. 1908: The most ancient splints. Brit. Med. J. p. 732-734.
Sourander, P.: Department of clinical pathology, Sahlgren Hospital, Univ. of Gothenburg, Sweden. Personal communications.
Wells, C. 1964: Bones bodies and disease. Thames and Hudson, London.
Wingborg, F. A. 1927: Från Valle härad med Varnhems kyrka och kloster, Höjentorp, Axvalla slott och andra märkliga platser inom bygden. Stockholm. (In Swedish).