

Even though this is an ongoing open trial and the results must be interpreted with caution, it is possible to draw certain tentative conclusions from the results. Oral gold salts are effective in reducing the clinical indices of inflammation, although at the dosage used laboratory data remained unchanged. Several patients experienced a remission in their disease. The treatment caused mild side-effects in a number of patients (61%) but these were of a very mild nature, treatment being stopped in only 3 (9,7%). In particular, haematological and renal complications were not of any consequence.

The drug is easy to use, is acceptable to patients and could possibly be used to best advantage in patients with a less active form of the disease, before the use of parenteral chrysotherapy or D-penicillamine is considered.

The author wishes to thank Smith, Kline & French Laboratories for their assistance and for supplying the test drug.

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## Penetrating wounds of the heart and great vessels — a new therapeutic approach

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### Summary

A series of 36 Black and Coloured patients, presenting during a 1-year period with life-endangering intrathoracic trauma secondary to assault, is presented. Penetrating wounds of the heart were documented in 32 of these patients, 6 of whom died almost immediately after having been brought into the Resuscitation Unit of Tygerberg Hospital, Parowvallei, CP. The remaining 26 patients had clinical features of cardiac tamponade and circulatory collapse, and in 4 of these patients an emergency thoracotomy was performed in the Resuscitation Unit as it was considered inadvisable to delay surgery until theatre had been arranged. Three of the latter 4 were discharged home completely recovered. Total peri-operative mortality was 13,3%, most deaths being due to lacerations of the left ventricle. Penetrating wounds of the ventricles accounted for some 85% of the total cardiac lacerations; other lacerations affected the pulmonary artery and its branches, the aorta, left atrium and internal thoracic artery. The incision most frequently employed at surgery was a median

sternotomy (53%), followed by left thoracotomy (40%) and right thoracotomy (7%).

Pre-operative emergency management based on pathophysiological principles is discussed. The fact that relatively inexperienced surgical registrars performed many of these operations with good results emphasizes the need for the establishment of resuscitation units in more peripheral hospitals where many of these patients could primarily be treated. These units would then be able to manage many of these patients, probably at an earlier stage than if they were referred to a teaching hospital such as Tygerberg.

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Stab wounds of the heart have existed as a popular method of committing suicide or expressing disenchantment with a fellow human being since long before the assassination of Julius Caesar two centuries ago. Even as recently as the beginning of the 20th century the outcome was invariably fatal and the management usually unsuccessful or entirely lacking. In 1709 Boerhaave<sup>1</sup> stated that penetrating wounds of the heart were all mortal. This was followed by Paget<sup>2</sup> stating in 1896 that surgery of the heart had reached the limits set by nature and that no new discovery could overcome the difficulties which wounds of this organ presented. At that stage the only form of management known was phlebotomy.

In 1896 Cappelen<sup>3</sup> unsuccessfully attempted to suture a human heart. In the same year Rehn<sup>4</sup> succeeded in his attempt to repair the cardiac wound of a patient who had been stabbed with

a table-knife, and in doing so unlocked the door to cardiac surgery. The next major advance in the management of penetrating wounds of the heart was emergency pericardiocentesis, advocated by Blalock and Ravitch in 1943.<sup>5</sup> This has remained a cornerstone in the management of cardiac wounds. During the succeeding 39 years the balance of opinion between conservative and surgical management has moved decisively and irrevocably in favour of the latter, and today the standard management of traumatic cardiac tamponade consists of resuscitation, emergency pericardiocentesis and emergency surgery.<sup>6-8</sup>

The operation is certainly 'one of the dramatic and potentially demanding emergencies that a surgeon has to manage',<sup>6</sup> but it is also potentially among the most rewarding. Furthermore, we believe that in the emergency situation in an outlying hospital the operation in most cases is within the capabilities of most medical practitioners who have had a period of postgraduate surgical training. This is a valid deduction from the results to be presented in this article — 47% of the emergency operations in this series were performed by surgical registrars with less than 9 months' surgical training experience.

**Patients and methods**

During 1981 36 patients with life-threatening intrathoracic trauma were referred to the Department of Cardiothoracic Surgery of the University of Stellenbosch, Tygerberg Hospital, Parowvallei, CP. This represents an average monthly incidence of 3 cases and constitutes 5,8% of all the major resuscitation cases seen in the General Surgery Resuscitation Unit of Tygerberg Hospital during the same 1-year period. This series includes only those patients who reached the hospital alive, and excludes all those patients with intrathoracic trauma in whom emergency surgery was not warranted.

Thirty-two of these 36 patients had a penetrating wound of the heart, while the remaining 4 patients had a major intrathoracic haemorrhage without involvement of the heart or pericardium. Thirty-five cases resulted from an assault with a sharp instrument and the remaining patient was injured with a handgun. There were no suicide attempts or accidental injuries in this series.

The race and sex incidence was also rather interesting. A total of 29 Coloured males (80%) and only 2 Coloured females (6%) were involved, while 5 Black males (14%) were assaulted. The series contained no Black females, no Whites, and no children. The average age of the patients was 24 years, the youngest being 17 years old and the oldest 41 years of age.

**Incidence and distribution**

Figs 1, 2 and 3 illustrate the incidence according to the month, day of the week and time of day respectively during the 12-month period January - December 1981.

The relatively quiet aftermath to the festive season in January and the low incidence of cases during the winter months are illustrated in Fig. 1. Friday and Saturday were the days of the week on which the majority of patients presented (72%) (Fig. 2). Two of the 3 patients that presented on a Thursday were injured either on Christmas Eve or New Year's Eve. Only 17 cases (47%) were encountered within 5 days of the end of the month. Seventy-five per cent of the patients were seen between the hours 18h00 and 02h00 of the same 'night' (Fig. 3). These times represent the time of commencement of anaesthesia, which is the only consistently accurately recorded time available.

**Clinical manifestations**

Six patients (16,6%) with penetrating wounds of the heart and

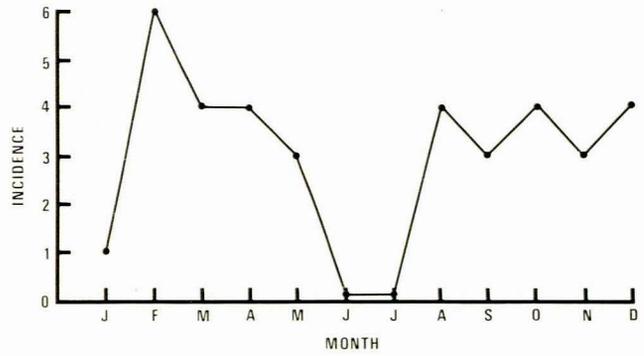


Fig. 1. The monthly distribution of penetrating wounds of the heart and great vessels. The relatively low incidence during the winter months is evident.

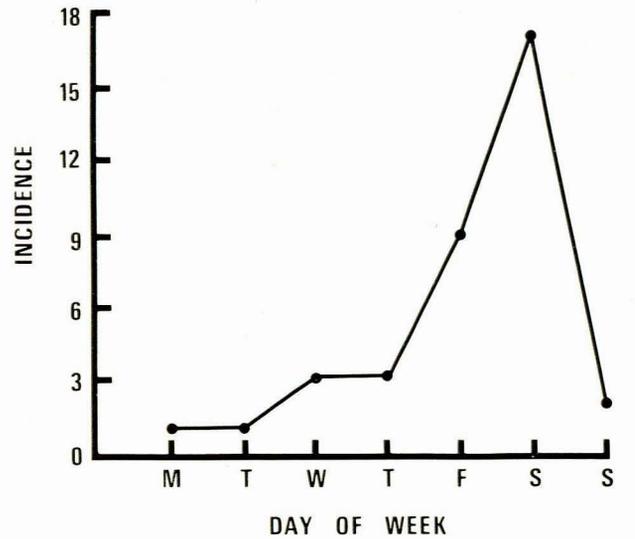


Fig. 2. Graph illustrating the peaked weekend incidence of penetrating wounds of the heart and great vessels; 72% of cases were seen on a Friday or Saturday.

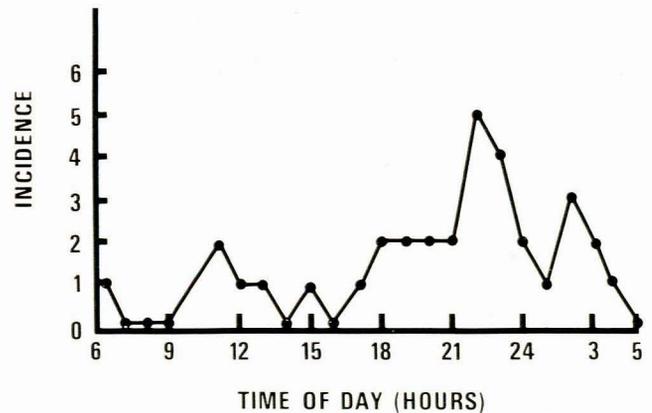


Fig. 3. Graph illustrating the times of day at which the patients with penetrating wounds of the heart and great vessels presented; 75% of patients were seen between 18h00 and 02h00.

great vessels died within minutes of being wheeled into the Resuscitation Unit. All of these had signs of overt cardiac tamponade and failed to respond to vigorous resuscitation, intubation and positive-pressure ventilation as well as pericardiocentesis. Efforts at resuscitation had been discontinued by the time the registrar in cardiothoracic surgery arrived.

The 26 patients with penetrating wounds of the heart and great vessels who were subjected to emergency surgery all had signs of circulatory collapse and overt cardiac tamponade. Cardiac tamponade was diagnosed when a stab wound located in the 'target area', i.e. between the second and sixth intercostal spaces within the mid-clavicular lines, was associated with low-output cardiac failure, distended neck veins, soft heart sounds and pulsus paradoxus. Four of these 26 had a cardiac arrest within a few minutes of the arrival of the registrar from our department and were subjected to an emergency left anterolateral thoracotomy on the trolley on which they lay in the resuscitation room.

Of the 4 patients with non-cardiac intrathoracic trauma, 1 patient had a virtual transection of the left upper lobe of her lung resulting from an extensive knife assault. She was in a state of preterminal cardiorespiratory failure when she was taken to the emergency operating theatre. Another patient had been shot with a handgun through his manubrium sterni and presented with paraplegia, a widened mediastinum and shock. Emergency aortic arch arteriography demonstrated that the left common carotid artery had been partially transected at its origin. The remaining 2 patients both presented with profound hypovolaemic shock and traumatic haemothoraces. Both patients had lost in excess of 3000 ml of blood through their underwater drainage tubes over a period of about 90 minutes before the bleeding could be controlled.

## Management

The initial resuscitation of all the patients was aimed at establishing adequate ventilation (either by means of an oxygen mask or endotracheal intubation and intermittent positive-pressure ventilation if deemed necessary). In addition to commencing a peripheral intravenous infusion of either warm Ringer's lactate or Plasmalyte-B solution, a No. 14-gauge 20 cm long intravenous catheter was placed in the subclavian vein and the central venous pressure (CVP) measured. Blood was despatched simultaneously for blood gas analysis, electrolyte estimation and blood grouping. About 200 mEq of sodium bicarbonate solution (i.e. 400 ml of the 4,2% solution which is available in a 500 ml Vacolitre) was rapidly infused and the residual metabolic acidosis was corrected once the blood gas analysis results were received. Pericardiocentesis was carried out in all patients in whom a penetrating wound of the heart was suspected. Emergency theatre facilities were then mobilized while the cardiothoracic registrar was notified, and the patient was then transferred to the theatre locale on his arrival.

In the 4 patients who underwent an emergency thoracotomy in the resuscitation room, the heart was decompressed, massaged and then sutured once it had started to contract again. The patient was then transferred to the operating room where the cardiac laceration was assessed and the thoracotomy incision closed.

## Results

Of the total series of 36 patients there were 6 (16,6%) with cardiac tamponade who had fixed dilated pupils and were therefore not subjected to surgery. The 30 patients subjected to emergency exploratory surgery are the subject of the analysis below.

Of the 4 patients who underwent thoracotomy under non-sterile circumstances in the Resuscitation Unit, all were initially revived and 3 were later discharged in good health. The 4th patient had a 2 cm laceration immediately parallel to the left anterior descending coronary artery in the left ventricle and died about 20 minutes later in theatre of irreversible cardiac arrest. There was 1 other operative mortality, also involving a laceration of the left ventricle, and a further 2 patients died, one on the 3rd

postoperative day and the other on the 5th postoperative day. Both had a stable cardiovascular status postoperatively but failed to regain consciousness. In these patients the clinical picture was that of diffuse cerebral anoxia or air embolism. One patient had been stabbed in the left ventricle while the other had a large laceration of the left upper lobe of the lung. This gave a total peri-operative mortality of 13,3% (4 patients out of the series of 30), and a peri-operative mortality associated with cardiac lacerations of 11,5% (3 out of 26 patients operated on). Lacerations of the left ventricle accounted for all of the latter deaths and were therefore the most important anatomical lacerations documented in this analysis.

Injuries to the right ventricle and left ventricle, in 13 (43,3%) and 9 (30%) patients respectively, together accounted for about 75% of all the cases in this series and 84,6% of the cardiac lacerations (Table I).

**TABLE I. ANATOMICAL DISTRIBUTION OF PENETRATING WOUNDS OF THE HEART**

Site of penetration	No. of cases
Left ventricle	9
Right ventricle	13
Pulmonary artery	2
Aorta	2
Left atrium	1
Internal thoracic artery	1
Major pulmonary vessel	2

The average period of hospitalization in the uncomplicated case was 6,9 days. Minor complications which did not influence the period of hospitalization included such conditions as minor postoperative atelectasis, minor blood reactions, and mental clouding which resolved within 2 - 3 days and in which no cerebral lesion could be confirmed.

Three traumatic ventricular septal defects (3/26) were recorded in this series, 2 of which were minor and required no surgical intervention; 1 patient, however, had a significant left-to-right shunt associated with complete heart block, both of which had to be treated surgically. Apart from the latter patient, there were 5 others with major complications (Table II); one patient had been stabbed through the first diagonal branch of the left anterior descending coronary artery and sustained an acute antero-septal myocardial infarction, while another patient had significant residual anoxic brain damage following a long hypotensive pre-operative episode. There were 2 cases of sepsis, manifesting as an empyema in one patient and localized skin

**TABLE II. PENETRATING WOUNDS OF THE HEART: MORTALITY AND COMPLICATIONS**

	No. of cases
<b>Mortality</b>	
Pre-operative	6
Operative	2
Postoperative	
(both anoxic brain damage)	2
<b>Complications</b>	
Transient air embolism	1
Empyema	1
Myocardial infarct	1
Paraplegia (bullet in spine)	1
Wound sepsis	1
Traumatic ventricular septal defect	3

necrosis in another. The last complication was paraplegia in the patient who had been shot with a handgun and in whom the bullet had lodged in the spine.

A left thoracotomy (40%) and median sternotomy (53%) were the favoured surgical routes of access, being employed in 12 and 16 cases respectively. In the remaining 2 cases a right thoracotomy was performed. The operation was performed by members of our department in all instances. In 14 cases (47%) the surgical registrar had had less than 9 months' postgraduate training at Tygerberg Hospital; only 1 patient out of the 14 died.

## Discussion

### Pathophysiology

The pericardial space normally contains about 25 ml of a lubricating serous fluid and is the single most important structure influencing the outcome of penetrating wounds of the heart and great vessels.

If the pericardium is widely lacerated, the patient will usually have an exsanguinating haemorrhage into the pleural cavity or mediastinum or through the external wound. However, if the pericardium is able to seal off by means of pressure or clot formation, as is usually the case in patients reaching the hospital alive, then the patient may survive the initial early period and develop a haemopericardium, the outcome of which is primarily determined by the rapidity of accumulation of blood within the pericardial sac. The vital consequence of the acute accumulation of blood or fluid within the pericardial cavity is the resultant increase in intrapericardial pressure to a level at which it inhibits venous return to the low-pressure right atrium and right ventricle (preload of the heart). This causes the CVP to rise. Since the right ventricle is primarily a volume-regulated pump, outflow to the left side of the heart via the pulmonary circulation is drastically reduced. This gives rise to decreased diastolic filling of the left ventricle as the diastolic period represents the low intracardiac pressure period and is thus the phase worst affected by the increased intrapericardial pressure. The cardiac output and aortic pressure therefore fall, leading to tissue hypoxia, acidosis and diminished coronary perfusion, factors which all contribute to decreased myocardial contractility, cardiac arrhythmias and cardiac arrest. This situation is analogous to right ventricular myocardial infarction due to obstructive atherosclerotic coronary artery disease.

The cardiovascular homeostatic mechanisms attempt to restore the blood pressure by: (i) maximizing peripheral resistance (afterload); (ii) increasing heart rate; and (iii) increasing preload by increasing the circulating blood volume via splenic contraction and redistribution of the blood. In our opinion management should therefore be directed towards augmenting specifically these pathophysiological mechanisms.

In those patients reaching the hospital alive there is usually clot plug formation in the cardiac wound during the initial period of hypotension, which, with the presumptive slight decrease in intrapericardial pressure due to the limited elasticity of the pericardium, allows the blood pressure to recover to a level of between 50 and 70 mmHg systolic. Asfaw and Arbulu<sup>6</sup> have tentatively suggested that the clot plug formation is directly proportional to the thickness of the cardiac wall penetrated and therefore indirectly proportional to the incidence of cardiac tamponade.

### Pre-operative management

Penetrating wounds of the heart and great vessels demand rapid clinical assessment followed by appropriate therapeutic intervention. Establishment of the presence of cardiac tamponade or imminent cardiac tamponade is vital to effective management. Immediate blood sampling for both group-

matching and assessment of acid-base balance and serum electrolytes is important. However, one cannot await these results before establishing adequate venous access in the form of a CVP line, as well as a further intravenous line. Oxygen administration is also vital to offset the hypoxic effect of the haemodynamic disturbance. The urgency of the clinical situation usually prevents the taking of supine chest radiographs on a portable X-ray machine, and the clinical diagnosis and management of the often concomitant haemothorax are therefore of extreme importance.

At this stage there are four priorities in the pre-operative management of the patient with a suspected penetrating wound of the heart: (i) empirical correction of the invariable metabolic acidosis; (ii) pericardiocentesis; (iii) transfer to the operating theatre as soon as possible; and (iv) maintenance of an adequate cardiac output until the patient is operated on.

A useful empirical formula to calculate the volume of a 4.2% solution of sodium bicarbonate (in ml) necessary to correct the metabolic acidosis is to multiply the estimated mass of the patient (in kg) by 6. This formula is based on an anticipated base deficit of 9. Therefore, if the patient weighs about 60 kg, 360 ml of sodium bicarbonate solution should be transfused.

Pericardiocentesis is best achieved by inserting a thick-bore needle attached to a 20 ml syringe (we use a No. 2 Braunüle cannula) just to the left of the xiphisternum and advancing the needle in the direction of the posterior aspect of the left shoulder, while applying constant suction to the syringe. Once the pericardium has been penetrated and the haemopericardium aspirated, the plastic cannula should be left *in situ* while the patient is transferred to theatre. It is worth noting that aspiration of as little as 20 ml of blood is often sufficient to alleviate the signs of cardiac tamponade.

In the attempt to maintain cardiac output before emergency surgery we believe that the following principles, which are based on the pathophysiology of the condition as discussed above, should be considered:

1. The critically raised intrapericardial pressure caused by the haemopericardium must be minimized by pericardiocentesis, drainage of a haemothorax and the avoidance of intermittent positive-pressure ventilation, if at all possible, until the surgeon is ready to operate. In our series all the patients who died pre-operatively were being ventilated by the time the surgeon arrived. If the patient needs ventilation he needs surgery at the same time. Ventilation should be reserved for those patients in whom the hypoxia is considered to be due to inadequate ventilation rather than inadequate pulmonary perfusion, as is usually the case in cardiac tamponade.

2. The systemic peripheral resistance (afterload) should be maintained and drugs which are liable to decrease sympathetic tone should be avoided. These would include analgesics, sedatives and those inotropic agents associated with vasodilation, for example isoproterenol.

3. The venous return to the right atrium (preload) must be augmented. The filling of the right atrium is inhibited by the haemopericardium and is determined by the difference between the CVP and the intrapericardial pressure. By transfusing the patient with a warm crystalloid solution (e.g. Plasmalyte-B or Ringer's lactate) one effectively increases the circulating blood volume, the CVP and the filling of the right atrium, thereby improving the diastolic filling of the left ventricle and the cardiac output. The only reservation is in penetrating wounds of the low-pressure atria which have poor plug formation in their lacerations, so that the plug may be dislodged by the relatively small increase in pressure achieved by transfusion. However, penetrating wounds of the atria are much less common than those of the ventricles<sup>7,9,10</sup> and accounted for only 1 case in this series. Transfusion with crystalloids would be of most benefit in those patients who present with hypovolaemic cardiac tamponade as evidenced by a relatively low CVP. This was the case in 50% of the patients reported by Szentpetery and Lower<sup>9</sup>

in 1977; 11 out of their 22 patients had recorded CVPs of less than 14 cm H<sub>2</sub>O. The aim of the transfusion is to achieve a blood pressure at which cerebral perfusion can be reasonably assured, i.e. 75 - 85 mmHg systolic, in an attempt to reduce the incidence of postoperative sequelae resulting from cerebral anoxia.

### Implications of the present study

The majority of patients with penetrating wounds of the heart do not reach the hospital alive. Sugg *et al.*<sup>8</sup> found that 81% of patients failed to reach the hospital alive. These patients generally have severe intracardiac lesions, such as rupture of the valve leaflets or papillary muscles.<sup>9</sup> This may well have been the case in the 6 patients who died within minutes of arriving at the hospital, although delay in getting to Tygerberg Hospital as well as delay in the performance of emergency surgery may have been crucial factors.

Tygerberg Hospital essentially drains an urban and suburban community where the alcohol intake as well as the crime rate is exceptionally high, especially among the Black and Coloured male populations. This socio-economic situation is very unlikely to alter significantly in the near future. Crimes and assaults leading to cardiothoracic injury are also known to occur in similar racial groups in the outlying rural communities, many of whom are employed in the wine industry and thus have ready access to alcohol. The average rural general practitioner or district surgeon is usually overawed by the appearance of such a patient and will usually, at most, insert an intravenous line and infuse fluids. The carrying out of a relatively simple life-saving procedure such as a pericardiocentesis is thought to be reserved for 'specialist' hands and is therefore postponed until the patient can be transported to a 'teaching' hospital, hopefully still alive.

It is important to note that although a left thoracotomy was undertaken in only 40% of the patients in this series, the anatomical distribution of the cardiac lacerations was such that it could safely have been employed in all but 1 of the patients. Carrying out an anterolateral thoracotomy is relatively simple and consists of making an approximately 15 cm long incision, begun about 2 cm to the left of the sternal edge (so as to avoid lacerating the internal mammary artery) and applied to the fourth or fifth intercostal space. Retraction of the ribs and incision into the pericardial sac will usually locate the cardiac

laceration which can be sutured effectively. This procedure should be employed in any patient whose condition is deteriorating haemodynamically. It would appear that medical personnel should be enlightened as to the management of penetrating wounds in the heart. This could be arranged by way of an 'attachment scheme' to the various teaching hospitals, all of which experience a high incidence of such trauma. Alternatively, members of the cardiothoracic surgery units at the large teaching hospitals could visit the peripheral hospitals and carry out their teaching 'on the spot' so as to make the rural or suburban doctor more familiar with his surgical environment. These rural medical personnel should be comforted by the fact that 14 patients (47%) were operated on by relatively inexperienced members of the Department of Cardiothoracic Surgery at Tygerberg Hospital, with an overall mortality of only 7,1%. If one accepts the possibility that many of the victims of such assaults are innocent parties, then this saving of human life is certainly worth the effort involved.

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## News and Comment/Nuus en Kommentaar

### Patients' views on mastectomy

How long does it take for a well-publicized message to filter through to the entire medical profession? Longer than you might think, according to a little study conducted by Feeley *et al.* in a provincial English city (*Br Med J* 1982; **284**: 1246). They interviewed 128 women who had undergone unilateral simple mastectomy for cancer more than 9 months previously. In certain cases there was still a lag between the discovery of the lump and referral to a hospital, since 5 of the women complained of a lag of more than 1 year from their initial presentation with a breast lump to the family doctor to their referral to a consultant, while another 14 women had suffered a delay of from 1 month to 12 months until referral. Nearly a quarter of the patients complained that they had been given insufficient information about their disease and its treatment before operation, and indeed 13 claimed that they were unaware of the likelihood of

mastectomy until they woke up without their breast. No less than 102 patients said that they had never heard of the Mastectomy Association, which is well established in Britain, although 26 had actually been given a booklet, *Living with the Loss of a Breast*, while in hospital. Nearly all expressed the wish for a special nurse/counsellor to guide them through the treatment period.

Many anxieties were expressed about the disfigurement and the prosthesis given to conceal it. Most patients also complained that they had not been allowed to try more than one type or size of prosthesis and 41 women often wore an alternative such as cotton wool. Moreover, 77 women rated their degree of satisfaction with the prosthesis as low.

The authors plead for specialist mastectomy counsellors, preferably with a nursing background, to counsel patients pre-operatively, to support them in hospital, and to oversee rehabilitation. They remark: 'The findings of this small study of 128 women who had had a mastectomy cause much anxiety'. You can say that again.