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THE CONJOINED TWINS OF KANO

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[WITH SPECIAL PLATE]

The term "conjoined (Siamese) twins" is usually applied to twins who are united bodily but possessed of separate personalities. It has therefore been used to include a great variety of twins monstrously joined, and has included partners who have shared various combinations of trunk and limbs. Those of surgical interest include the so-called "symmetrical conjoined twins," though this term is perhaps unfortunate in that conjoined twins are seldom completely symmetrical; they differ from each other usually to some degree in appearance, and their internal organs may partly or wholly each be a mirror image rather than a replica of their partner's.

Formation of Conjoined Twins

It is usually assumed that conjoined twins are monovular and due to fission of an embryo. If fission occurs at the stage of the inner cell mass before the embryonic disk has separated, separate twins result. If the twinning occurs after separation of the embryonic disk, there is only one amniotic sac. If the centres of axial growth are at this stage far enough apart there are separate twins in a single amniotic sac. If the centres of growth were not sufficiently separate the intermediate area between the two centres of axial growth might be shared and conjoined twins result (Potter, 1952).

It has never been completely proved that conjoined twins are in fact monovular. It is conceivable that separate twins might become joined from fusion of the closing edges of the neural grooves, for example, or from fusion of some other epithelial surfaces with their underlying mesodermal masses; but this would require disappearance of intervening amnion, a rare accident, as well as fusion of the twins. It is certainly curious that conjoined twins always differ from each other slightly in size and appearance, and are seldom so precisely identical as separate monovular twins are. Seventy-three per cent. of conjoined twins exhibit mirror imaging, while separate one-egg twins show this abnormality in only 22%, the mirror imaging taking the form of a degree of *situs inversus viscerum,* which has never been explained satisfactorily. I have a record, obtained directly from a traveller, of Chinese conjoined twins, one of whom was a eunuch. There is also a report of twins joined at the pelvis, one of whom suffered from hypertension (Jones *et al.*, 1948). In one reported pair there was a hare-lip deformity in the case of one only, and, as in the Townsend twins of Alberta (Allin, 1953), the heart is often normal in one twin but the seat of Fallot's tetralogy or some other congenital cardiac defect in the other. In this connexion it should, however, be remembered that in parabiosis of any kind one partner always becomes dominant. If two identical twins from a normal litter are artificially joined by parabiosis one almost invariably outgrows the other, contributing more to the total organism and taking more from the total organism than its partner. If conjoined twins were ever the result of the fusion of binovular embryos it would be likely that on some occasion a blood-group chimera would occur; this has never been demonstrated, but it apparently has never been sought.

Types of Twins

Conjoined twins may take the form of an *omphalopagus* (joined at the navel); a *xiphipagus* (joined at the lower sternum); a *thoracopagus* (joined in the chest); a *craniopagus* (joined by the heads); or a *pygopagus* (joined at the pelvis). The bridge of fusion may include an important internal organ. An omphalopagus may have a fusion of the two small intestines, or of the stomach, or of the liver. A craniopagus may have the two brains joined by a bridge of nervous tissue. When union is at the pelvis, urogenital organs may be shared, or if union is at the sacrum the spinal cords may be single at the level of the union. Rarely, one twin is included in the body cavity of the other as an "included foetus" (Farris and Bishop, 1950).

The frequency of occurrence of conjoined twins is difficult to ascertain. Potter reports one specimen of symmetrical joined twins in the Chicago Lying-in Hospital in 60,000 deliveries; during the same period there was no example of such union in embryos or foetuses. The frequency of reports of conjoined twins is increasing, but it would seem that this is due to the increasing accessibility of very large populations in Asia and Africa, to the greater possibility of the successful birth of conjoined twins in improved modern obstetrical circumstances, and to the lessening likelihood now of conjoined twins being sacrificed as monsters at birth. My belief is that we may expect each year, over the world as a whole, the birth of half a dozen or more conjoined twins capable of separation. A number of survivors from the operation of separation of Siamese twins have come to my notice in the past few months, and not all of these have been reported in the medical press.

Only a minority of conjoined twins seem to cause dystocia, though at least one case of obstructed labour from this cause is reported (Roxburgh, 1946).

Some Historical Examples

A number of conjoined twins have become historically famous. The earliest case on record seems to be that of the " Biddendon Maids " born in A.D. 1100 in England, united from hips to shoulders and with only one pair of upper and one pair of lower extremities shared between them. The " Florentine Twins," born in the fourteenth century and the subject of a bas-relief in the Church of La Scala and of a sonnet of Petrarch's, seem to have had three lower extremities between them and three upper, though successive mediaeval authors vary in their descriptions and illustrations (Belloni, 1950). The " Scottish Brothers," joined from the waist down but separate above it, lived for 28 years at the Court of James III of Scotland in the latter part of the fifteenth century. The opposite abnormality—one head and chest and a double abdomen and pelvis, with four inferior extremities—has also been described (Rohrbach, 1950). In the sixteenth century female conjoined twins with three legs, the central one equipped with ten toes, lived at Middleton, in England (Rueff, 1554), and during the same century there was a similar monster, carrying, however, only five toes on each of the three lower extremities, alive at Viaban in France. The " Hungarian Sisters " were born at Szorny in 1701 and survived in a convent for 22 years. The famous " Siamese Twins," Chang and Eng (1811–74), have been fully documented elsewhere (Luckhardt, 1941). Born of Chinese parents in Siam in 1811 as a xiphipagus, they were discovered at the age of 13 by a British merchant. Removed to North America, they were shown in his circus by Barnum, married English sisters, and settled down as farmers in North Carolina under the name of Bunker. As in the case of most other conjoined twins, when one died the other refused separation. Other conjoined twins include the " Sardinian Sisters " (1829–?), the Negro slave sisters Millie-Christine (1851–?), the " Bohemian Sisters " Rosa-Josepha Blazek (1878–1922), and many subsequent examples (Newman, 1942). There are at least three dozen fully documented instances in the literature of conjoined twins born alive. Hindu twins, Guarabai and Guaganbai, were on exhibition at the Paris Exposition of 1931. The Godino twins, born in the Philippines, applied for United States' citizenship. They were perplexed when the official response to their application was a warning that military service would be required of them ; their sacral junction would have rendered it impossible for them both to have obeyed marching orders simultaneously (*N.Y. St. J. Med.*, 1937).

Previous Operations

Scammon (1925) recorded and described the operations performed for the separation of conjoined twins, including that performed by Doyen in 1902 for the separation of the Radica–Doodica sisters, one of whom had developed active tuberculosis : the tuberculous sister died, but the healthy survived. The earliest attempt at surgical separation is said to have been made by Dr. Farius, of Basle, in 1689, but I have not traced the record of this operation.

In October, 1912, conjoined twins were successfully separated at the Military Families Hospital, Portsmouth, by a R.A.M.C. officer whose name cannot now be traced. One of the sisters of this pair is alive to-day, age 41, and the scar of her operation can be seen on the lateral aspect of the hip. The other sister died of pneumonia at the age of 4 months, but there are no records to show whether or not she in fact had congenital heart disease. This would appear to be the first successful separation of conjoined twins.

Dr. Holm, of Minnesota, successfully separated conjoined twins joined by the xiphoid cartilage on January 8, 1927, and they were alive and well nine years later (Holm, 1936). Dr. D. W. McLaren (1936) also successfully separated conjoined twins of a Hausa woman in the Sokoto Emirate of Nigeria on June 16, 1935, and the separated twins are alive and well to-day (McLaren, 1953). Here again the junction was of skin, subcutaneous tissue, and cartilage at the level of the xiphoid process. Three further separations were recorded last year in America in the medical and lay press. In one of these (Carolyn Anne and Catherine Anne Mouton) the junction was pelvic and both girls survived, one with an artificial anus. The second example, in Cleveland, Ohio, was a separation of twins joined by cartilage at the xiphisternum, both again surviving (Reitman *et al.*, 1953), and the third (Grossman *et al.*, 1953) was a craniopagus, with a common sagittal sinus which necessitated the sacrifice of one child, the other surviving. In 1953 a craniopagus was born in Bonn, Germany, but operation was, I understand, refused. A xiphipagus born in Molenend in Friesland awaits operation. A thoracopagus born in Greenock, Scotland, on March 20, 1954, survived for rather more than a day, and conjoined twins born in Hamburg, Germany, on the same day, are still alive at the time of writing.

Hazards of Operation

Surgical success is most likely to be obtained when the union between conjoined twins is only of skin, subcutaneous tissue, and perhaps cartilage. I have recently been informed of several cases in which an umbilical junction of minor extent has been successfully separated just after birth and the event not thought worthy of medical record. The chance of success should also be high in twins joined at the xiphisternum by skin and cartilage only. Where a vital organ is shared—the liver or the brain—the division of that organ may render operation hazardous. The Edendale twins shared a common ileum (Tibbit, 1951). Pelvic junctions also offer particular difficulties, for frequently the generative organs, urethra, or rectum may be single (Fox and Barnes, 1950), or may be so closely associated with each other that surgical separation is extremely difficult. Sacral unions can be divided often only with sacrifice of one spinal cord at that level. Cranial unions may involve the division of brain substance (Smellie and Starr, 1950), or the loss to one infant of a blood vessel vital to the survival of its brain. In any event, and however great the risk of the death of one or both children, it would seem that operation should nearly always be undertaken if the children are known each to have a full complement of the organs and tissues necessary for separate life. In very extensive union there may be no prospect at all of separation, as in those historical monsters who lack a full complement of limbs, or who share a single pelvis or an even more extensive length of trunk.

In the case of a stillborn premature thoracopagus which I had an opportunity to dissect in February, 1954, by the courtesy of Dr. T. K. Owen, of Bournemouth, union was exceedingly complex. A bridge extended from just below the chin to the navel and the chest cavities and abdominal cavities were shared. Each foetus had a mouth, pharynx, and larynx, but there were a single oesophagus, stomach, duodenum, and small intestine down to the level of Meckel's diverticulum ; here there was a dilatation from which the lower ileum passed to each foetus, and each foetus had a complete colon. There were only one heart and thoracic aorta, and one liver—a misshapen organ lying vertically in the middle of the bridge with only one common bile duct and portal vein, and with one pair of hepatic veins. The urinary tracts were normal and separate. There was a single trachea terminating in an arborization of bronchi which ended blindly, and the lungs were represented by multiple islands of solid tissue which had no communication with the bronchi. Such monsters could in no circumstances have survived to live separately.

The diagnosis of conjunction, usually made during labour, has only twice been made before labour has begun (Graber, 1945 ; Becker, 1950).

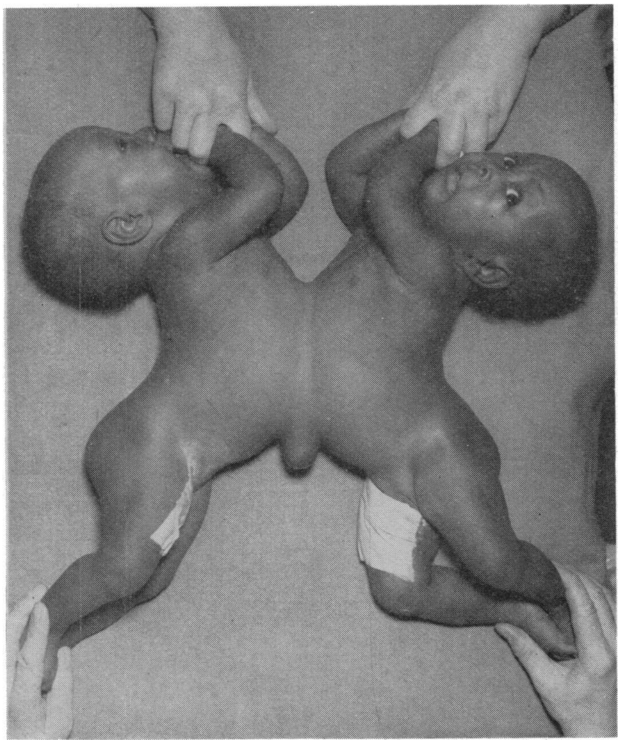

FIG. 1.—Photograph of conjoined twins showing hernia of common umbilicus. (Copyright reserved.)

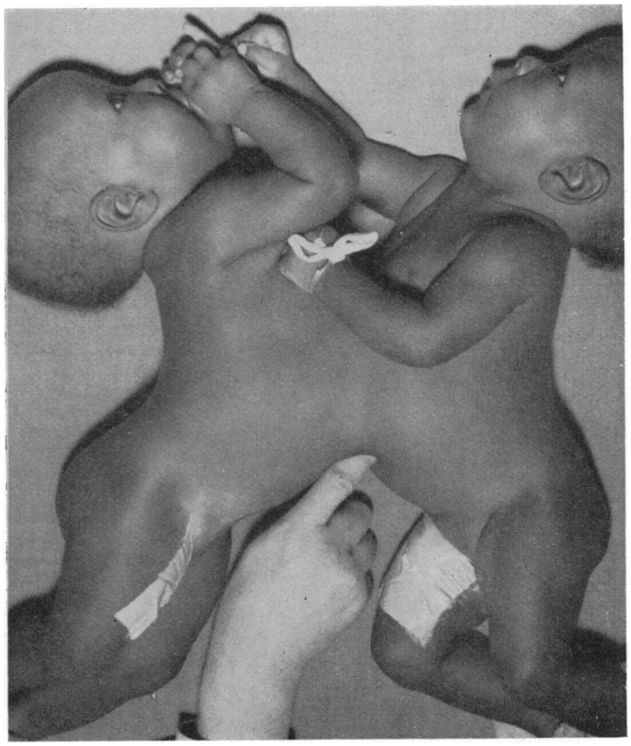

FIG. 2.—Investigating finger invaginating hernia into peritoneal cavity. (Copyright reserved.)

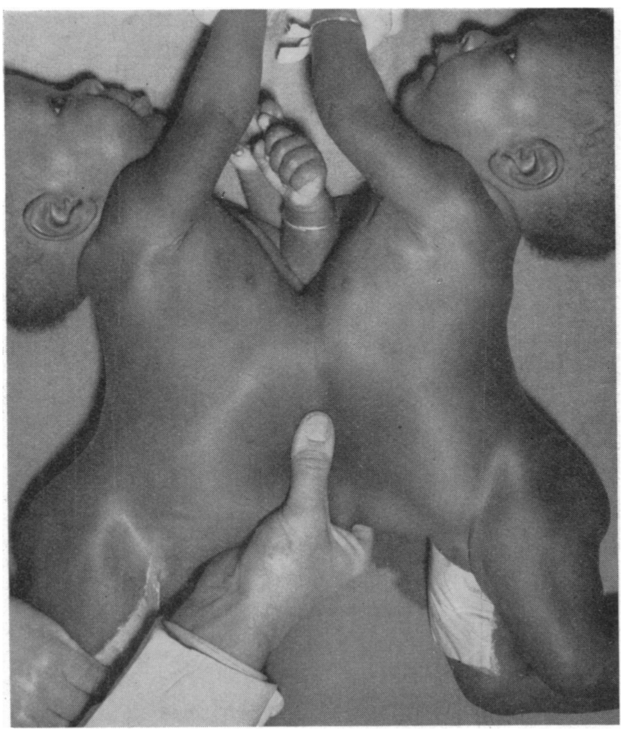

FIG. 3.—Lower part of "bridge" joining twins. (Copyright reserved.)

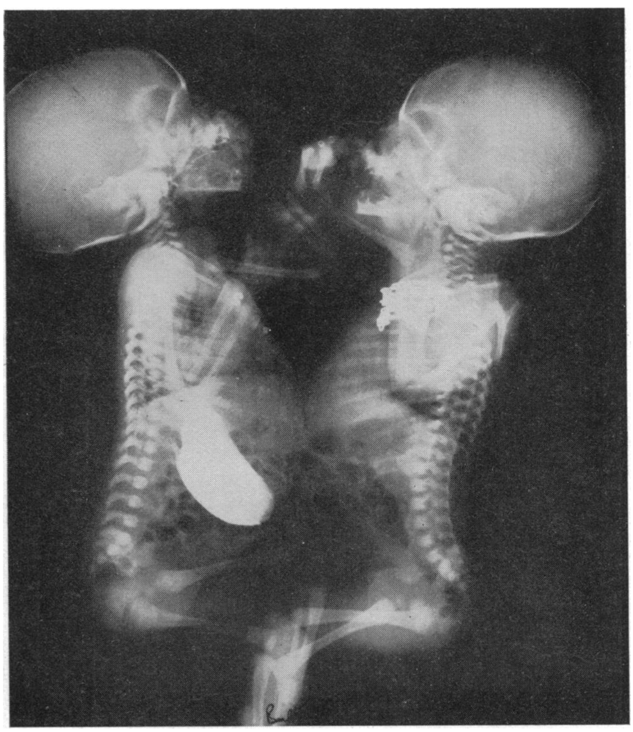

FIG. 4.—Barium meal filling stomach. (Copyright reserved.)

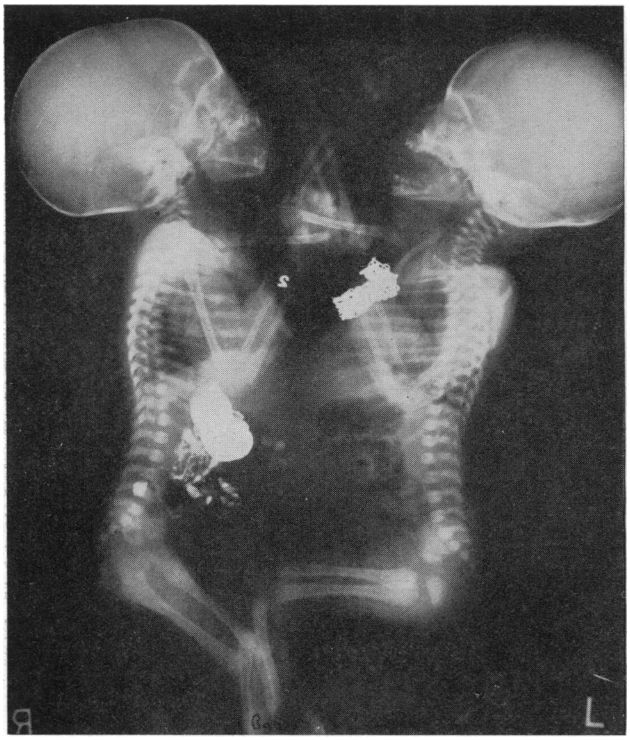

FIG. 5.—Barium meal showing small intestine. (Copyright reserved.)

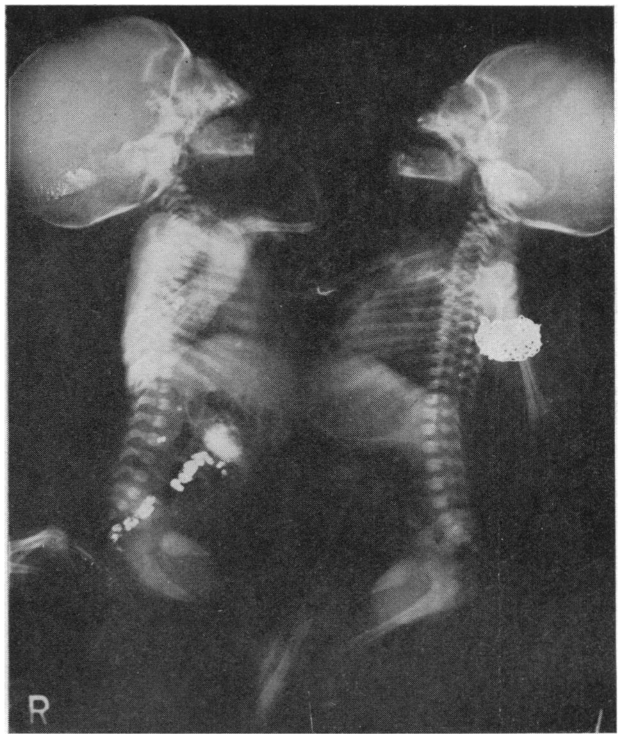

FIG. 6.—Barium meal showing colon and rectum. (Copyright reserved.)

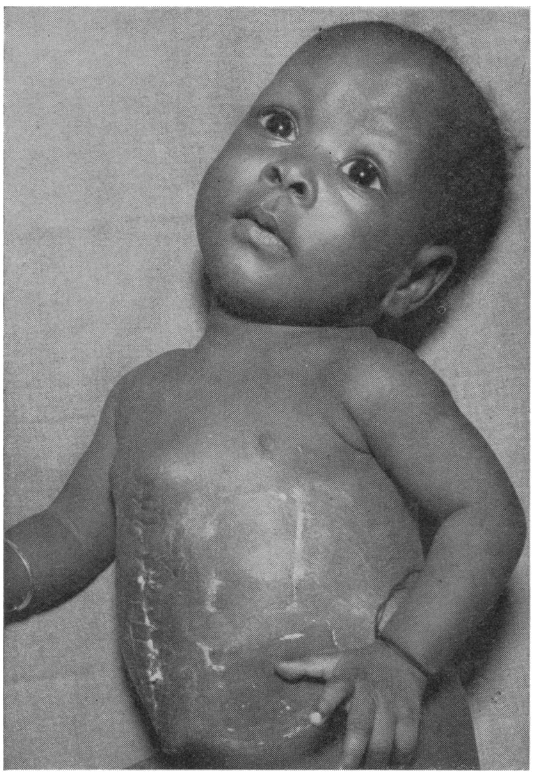

FIG. 7.—Photograph of surviving twin. (Copyright reserved.)

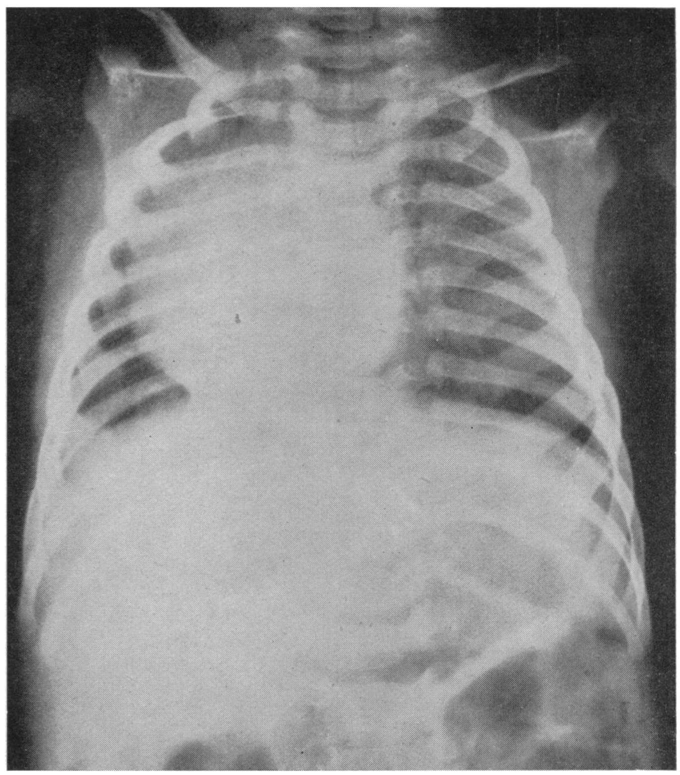

FIG. 8.—*X*-ray film of surviving twin showing dextro-rotation of the heart. (Copyright reserved.)

On March 22, 1954, a thoracopagus was born at Hastings, Sussex. The mother's previous obstetric history was of a miscarriage at 12 weeks gestation in 1947 and a full-time pregnancy in 1949. There was a history that the paternal grandmother had had three sets of normal twins. There was a pre-natal diagnosis of twins, both presenting by the head. Labour began at term on March 22. One head presented at the vulva next morning, but further progress was arrested and traction was in vain. The presenting baby died during these efforts to deliver it. The obstetrician (Mr. John F. Foulkes) was summoned, and his examination revealed the presence of conjoined twins. In view of their size delivery by the abdominal route was undertaken and accomplished, both babies being now dead. The mother has made a good recovery.

These twins were joined from the sternum at the level of the third costal cartilage to the umbilicus. The lower part of the communicating bridge took the form of a substantial exomphalos through the wall of which four umbilical veins, one pair on each aspect of the bridge, could be seen passing from a single placenta, diverging from each other on each aspect of the bridge and coursing together again, appearing to join at the edge of the exomphalos. Dissection of the specimen showed that each infant had an oesophagus and stomach, but that the two pyloric canals entered a single duodenum which was continued as a single small intestine to a point about half-way along the small intestine, where there was a pouch resembling a Meckel's diverticulum, though placed at a much higher level than usual; and from this pouch two separate enteric channels continued, one to each infant. The large intestines were normal. The liver was joined and no gall-bladders could be found. There appeared to be two sets of bile passages and each infant had a pancreas. A single heart, anatomically abnormal in a complex way, served both infants, and only one of the infants was possessed of an aorta. In the other infant no vessel or vessels suitable to take the place of the aorta could be found. These infants, though externally not substantially dissimilar to the conjoined twins of Kano, could not have been separated with any hope of the survival of both, and it seems unlikely that even one of them would have survived operative intervention. The complexity of their union shows the need for the most extensive possible investigation before the surgical separation of conjoined twins is attempted.

The Kano Twins

The conjoined twins which are the subject of the present paper were born in Kano, Nigeria, to a mother of Ibo race, on July 25, 1953. They were rotated at birth with respect to each other; one presented as a vertex, the other as a breech. A diagnosis of plural birth had not been made. The twins were successfully and safely delivered by a pupil midwife. Their weight at birth was 7 lb. 13 oz. (3.5 kg.) They were nursed at the breast, the mother learning to support them both in a suitable position for feeding together.

X-ray examination after the feeding of barium to one twin showed already while they were in Nigeria that the alimentary tracts were separate.

The twins were admitted to Hammersmith Hospital on Friday, November 13, 1953. Both were then in good health, and their joint weight was 19 lb. 1 oz. (8.7 kg.). One twin, Wariboko, was noticeably larger and more active than the other, Tomunotonye, and the facial appearance of each was quite distinct. They were not in the literal sense identical even though presumably uniovular.

The twins were joined by a bridge which extended from the sixth costal cartilage to the navel. The bridge was 14 cm. in its long vertical diameter and 37 cm. in circumference. There were a single common navel and an umbilical hernia which depended from the lowest part of the bridge (Fig. 1). This hernia could be invaginated, the invaginating finger passing easily into both peritoneal cavities (Fig. 2), which showed that the peritoneal cavities communicated at least in the lower part of the bridge. There was a firm ring of muscle around the neck of the hernia, which admitted two fingers, and it thus seemed certain that the bridge had a substantial muscle wall in its greater part. In its lower part the bridge could be compressed between finger and thumb (Fig. 3) so that its two walls met. In its uppermost part the bridge contained a hard tissue which was deduced to be cartilage: it seemed to arch over the upper part of the bridge formed by the fusion of the sixth, seventh, and eighth costal cartilages, and the lower part of the sternum. Even below palpable cartilage the bridge could not be fully compressed in its upper half.

A heart beat could be heard over the chest of each child, but it was impossible on auscultation to decide whether the beat was separate. The children breathed in unison and consequently sucked synchronously when fed. This was a matter at first of some apprehension, in case the diaphragms should be extensively intermingled and the pericardial cavities perhaps in communication with each other. It was then recalled, however, that animals artificially joined in parabiosis breathe synchronously, apparently as a matter of convenience, and it was hoped that synchronous breathing was a matter of convenience in these twins rather than a sign of seriously extensive anatomical union of their respiratory organs. It is perhaps of psychological interest that each infant sucked her own and her sister's thumb almost indiscriminately and with equal and mutual satisfaction.

A series of special investigations was undertaken to decide whether operative separation afforded any prospect of success.

X-ray Examination

A straight *x*-ray film failed to demonstrate visibly the cartilage bridge between sternums and ribs. (This feature can be seen in Figs. 4, 5, and 6.) Both spines were lordotic from the infants constantly straining away from each other, and the sternums both sloped forward towards each other from the upper to the lower ends. The heart shadows were clearly separate from each other. In repeated *x*-ray examinations the intestines filled the lower part of the bridge, but in none of the very numerous plates were hollow viscera seen to occupy the upper third of the bridge. In the very uppermost parts of the bridge a clear gap was observed between the two livers and the outlines of the opposing faces of the two livers were thought to be distinguishable; yet there remained a rather hazy shadow between these two outlines, and a bridge of liver tissue crossing from one infant to the other could not be excluded.

An opaque-meal examination was undertaken in Nigeria, barium being fed to one infant. This showed clearly that stomach (Fig. 4), small intestine (Fig. 5), and colon and rectum (Fig. 6) were separate for each child. It showed in addition that the pylorus of one child lay at least 3 in. (7.6 cm.) from the pylorus of the other, and therefore it was assumed that the two duodenums were substantially separate from each other, and consequently that at least the lower ends of the common ducts were separate too.

Cholecystography was next performed. The gall-bladders were both visible, well separate from each other. Consequently it was deduced that the common ducts must be separate at their upper ends and, since their lower ends were also considered above to be separate, presumably throughout their whole length. It was assumed that if the bile ducts were separate the portal veins would be separate also.

Intravenous pyelogram was performed at the same time as blood and circulation studies were done in order to preserve at least one great saphenous vein in each baby to be used for transfusion at the time of operation. An intravenous catheter was in each infant passed by way of the saphenous vein into the common iliac vein. A pyelogram showed that each infant had two kidneys placed well back in the paravertebral region. From this it was deduced that the renal arteries, and probably therefore the aortas, were in their normal situations. Anomalies of the great vessels are frequent in conjoined twins and a common ventral aorta was to be feared. The pyelogram seemed to exclude this particular danger. The bladders were well outlined, separate from each other, and there was no visible junctional canal between them, as might be found by the union of one allantois with the other.

Electrocardiography

Electrocardiographic studies were undertaken by Dr. T. Counihan. They proved to be of special cardiological interest sufficient to require separate description, and Dr. Counihan's description of the electrocardiographic changes and discussion of their implications will be described in a separate paper. The individual electrocardiographs of both children were essentially normal. In the joint electrocardiograph (Fig. A) the Wariboko complex was inverted, and

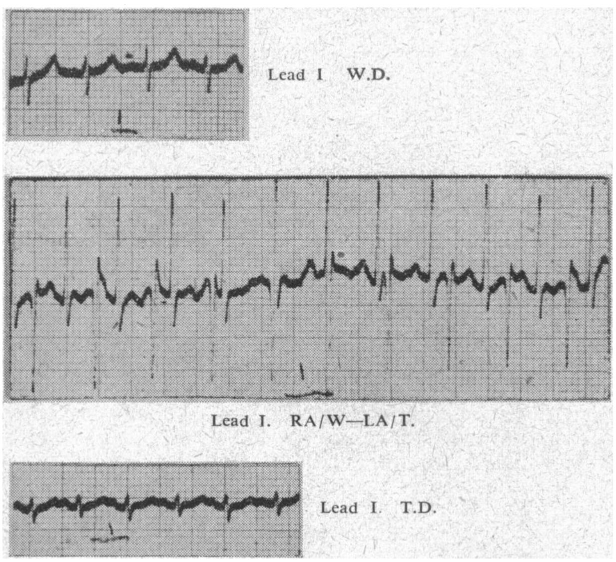

FIG. A.—Joint electrocardiograph. Wariboko complex inverted. Heart rates different.

this infant was shown later to have a dextro-rotation of the heart. This joint tracing showed clearly that the heart rates were different.

Investigation with Radio-isotopes

Mr. N. Veall, formerly of the Radiotherapy Unit, and Dr. P. L. Mollison, of the Transfusion Research Unit, of the Medical Research Council, both situated in Hammersmith Hospital, undertook a study of the circulatory connexion between the two infants. A known dose of radioactive red cells was injected by intravenous catheter into twin I. Gradually the injected cells, circulating across the bridge, mixed with the circulating blood of twin II. The concentration of radioactive blood in twin I consequently gradually fell, and the concentration of radioactive blood in twin II, as measured in successive specimens by Geiger-Müller counter, gradually rose, until equilibrium was reached with complete mixing. From the rate at which the proportion of radioactive cells in twin II increased the rate of blood flow across the bridge could be deduced. Mr. Veall prepared a graph (Fig. B) which showed the rise in radioactivity in the blood of infant II and the fall in that of infant I. The curve is, as was expected, an exponential one, but it will be seen that there is a slight time-lag in the early part of the curve. This would be compatible with the blood in the injected infant having to complete nearly the whole circle of the circulation, passing through not only pulmonary and systemic capillary beds but also the hepatic sinusoid bed before crossing the bridge. Mr. Veall's curve shows that complete mixing was obtained in 29 minutes, and half-mixing was reached in 5 minutes. The logarithmic curve and formula for determining the rate of crossing is given in Fig. C. It is thought desirable here to publish Mr. Veall's pre-operative report in full.

Consider two tanks A and B each having an equal volume V ml. They are connected together so that there is a flow of

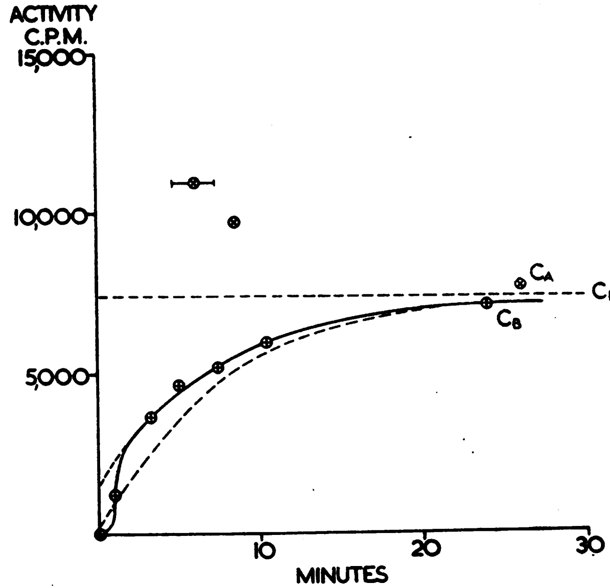

FIG. B.—Graph showing rise in radioactivity in blood of infant II and fall in infant I.

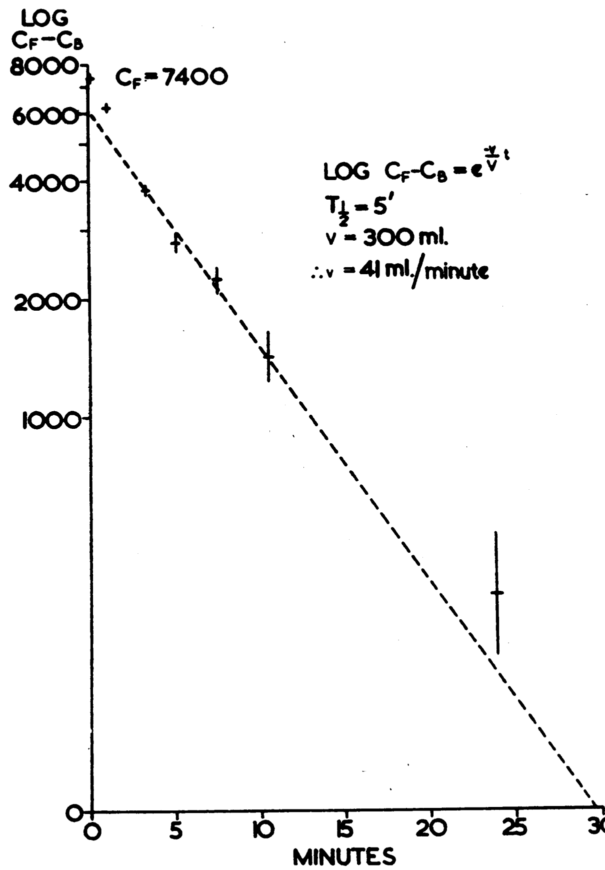

FIG. C.—Logarithmic curve and formula for determining the rate of crossing.

v ml./minute between them. A marker substance is added to tank A and its concentration C is measured in both tanks as a function of time. Assuming perfect mixing, the concentration of the marker in each tank is given by the equations:

$$(1)\ C_A = C_F\,(1 + e^{\frac{-v}{V}t});\ \text{and}\ (2)\ C_B = C_F\,(1 - e^{\frac{-v}{V}t})$$

where C_F is the final equilibrium concentration after mixing is complete. The two curves have the form shown in Fig. B, one being the mirror image of the other. By plotting the logarithms of either ($C_A - C_F$) or ($C_F - C_B$) against time a straight line is obtained (Fig. C), whose slope gives the value of the ratio v/V. Finally the volume V can be calculated from the value of C_F and a knowledge of the amount of marker added, so that the flow v can be calculated.

Two assumptions were made:

(1) That the blood volumes of the infants were equal: this assumption greatly simplifies the mathematical treatment and within the limits of the experimental data available appears to be reasonable.

(2) That there is perfect mixing: in the first two or three minutes this is certainly not true, so the very early points cannot be relied on for determining the slope of the logarithmic plot.

Injection of labelled red cells was made into infant I. Only two well-timed samples were obtained from that infant, and one sample which was uncertain because of catheter blockage. Six well-timed samples were obtained from infant II, and these gave a value for the ratio of v/V of about 1/7. The one-minute sample was ignored for this purpose (see assumption (2) above). A reliable value of C_F was obtained by means of samples from both infants when mixing was almost complete. This gave a combined blood volume, using the normal procedure and corrections, of 600 ml. for the thoracopagus, whence V (blood volume of each twin) equals 300 ml. Hence the blood flow, v, between the two infants is 40 ml. per minute in each direction. This figure is thought to be accurate to within $\pm 10\%$.

It will be seen that the actual points in figure B, except for the first and the last, do not fit the exponential curve which suits a half period of five minutes; the other points can be fitted by another exponential curve which extrapolates back to a value of 1,400 c.p.m. instead of zero. It is therefore necessary to account for a relatively sudden influx of labelled red cells, sufficient to increase the activity of the blood in infant II by about 1,400 c.p.m. and occurring at about one minute after injection.

A reasonable interpretation of this phenomenon would be as follows:

Assume that one-third of the cardiac output (blood volume) passes to the liver—that is, 100 ml. When the labelled red cells are injected no appreciable mixing will have occurred, and one-third of the labelled red cells will pass into the liver circulation of infant I as a wave. If 30 ml. of the liver flow then passes directly to the liver from infant II, and thence into the circulation, then the effective increase in concentration in infant II will be given by $14{,}800 \times \frac{1}{3} \times 0.3 = 1{,}500$ c.p.m.

This effect takes about one minute to manifest itself at the sampling point, a time consistent with the length of the circuit involved.

If the above assumption about liver flow is true a completely common liver circulation, with a common portal vein, would give about 50/50 partition. The implication of the figures obtained is that about 60% of the liver tissue is shared.

It thus emerged from the circulation studies that 41 ml. per minute of blood crossed the bridge in each direction. It was a guess that perhaps 5 to 10 ml. per minute might cross in the skin and muscle of the bridge. There was thus 30 to 35 ml. per minute to account for by a cross-circulation in some tissue other than skin and muscle. Assuming the liver circulation to be one-third of the total circulation it might be taken that 100 ml. per minute passed to each liver, or to each half of a shared liver. For 30 to 35 ml. to cross the bridge in each direction by way of the liver would mean that there was substantial mixing in the central 60% to 70% of a shared liver. The presumption that liver lay in the bridge was thus extremely strong.

Decision to Operate

The investigations seemed to show that both infants were fully equipped with all the organs necessary for separate life. It was not possible to predict whether the separate organs would necessarily function adequately after separation, but it was unfortunately not anticipated at this point that one of the pair might be contributing more, and one less, than the other to the total endocrine production. The only hazard of operation would seem to be the liver union which was confidently predicted; but this was not felt to be an insoluble barrier, though division of a common liver might well add to the shock of the operation. There was no previous record of the successful separation of twins so extensively conjoined. The investigations seemed to have shown that the portal veins and common bile bucts were separate. It was decided to operate without further loss of time to avoid increasing the spinal lordosis and the forward angling of the sternums.

The Operation

The mother was prepared for operation in case a vein or fascia graft or temporary skin cover by homograft should be required.

INSTRUMENTS

Only two special instruments were included in our armamentarium, a liver tourniquet of fine soft rubber (Penrose) tubing, as used by Dr. Allin, of Edmonton, who lent his film of a previous separation, and Schumacher intestinal clamps for application to the liver bridge if it was narrow enough.

ANAESTHESIA

Since the vascular communication across the bridge gave complete mixing of the twins' blood only after 29 minutes it was obvious that both must be separately anaesthetized, and two anaesthetic teams were arranged. Nitrous oxide and oxygen anaesthesia was chosen, and each infant was to be separately intubated and to be anaesthetized by means of a separate anaesthetic apparatus.

For an operation of such magnitude on babies so young blood transfusion was obviously essential, and Dr. P. L. Mollison, Director of the Medical Research Council Transfusion Research Unit, catheterized the remaining saphenous veins so that transfusion would be entirely dependable.

The twins were placed on an operating table with the headpieces and footpieces dropped, and the double anaesthetic was induced without difficulty. A remarkable phenomenon was observed during the induction of anaesthesia. As has already been stated, the respiration of the twins before operation was synchronous. As the induction of anaesthesia proceeded, and while the children were breathing still voluntarily, each through its own anaesthetic apparatus, the character of the breathing changed, and a kind of seesaw respiration developed, one baby inspiring as the other exhaled. Gradually the tempo of respiration again changed, until each settled down at its own pace. The explanation of these respiratory changes must be exceedingly complex. Once induction was complete intubation proceeded and was effected without difficulty.

TOWELLING THE TWINS

The special arrangements for towelling were learnt also from the Canadian film. A team of nurses supported the twins horizontally over the operating table and well clear of it, while the skin of the whole trunk of each, and of the bridge between them, was cleaned. A series of four towels were then applied to the babies, one towel wrapping the head and upper chest of each, and the others the lower extremities. The towelled babies were then placed on the operation table. Two surgical teams were in readiness, each consisting of surgeon, assistant, and instrument nurses, the two surgeons to separate the twins and then each to conduct one closure. Other specialists were additionally available to advise in the solution of unexpected problems in particular fields, and an anatomist to help unravel internal anatomical abnormalities, especially the complicated and varied venous plexuses sometimes present in such twins on the under surface of the liver.

Initial Phases

It was decided first to explore the bridge directly through its presenting obverse surface, the incision being made initially from the cartilage bridge to the navel. The alternative would have been to start at the lower limit of the bridge, dividing the parietes on both obverse and reverse aspects, and closing the two abdomens from below upwards *pari passu* with the division. This might have been less shocking, but would have been clumsy and slow, and control of escaping viscera might have been awkward. The anterior approach to the abdominal cavity and to the liver, leaving the parietes on the far side undivided until the end of the operation, would, it was thought, permit the intestines to be easily packed off throughout the whole period of operation. The number of hands in the operation field was restricted to four, which ought to be sufficient for control of the abdominal contents and for retraction. A multiplicity of hands is a hindrance in the neighbourhood of so small a wound.

The skin having been divided, a reasonably thick sheet of abdominal muscle presented, equal to the whole thickness of the normal infantile abdominal wall, though not separated in layers. When this was divided, peritoneum appeared in the lower part of the wound and the liver bridge could be detected in the upper part. A cushion pad of suitable size inserted under the bridge was now found to enhance the exposure substantially.

Since it was known that there was a common peritoneal cavity, extending at least across the lower part of the bridge, where the hernia could be invaginated, the peritoneal cavity was first opened here. It was now clear that the peritoneal cavities communicated only at the lowest extremity of the bridge in the neighbourhood of the hernia. The peritoneal incision had in fact entered the peritoneal cavity of baby I. It was extended now up as far as the liver, and it was clear that the peritoneal cavities communicated freely below, but above were separated by a slender dividing veil which stretched across the whole thickness of the bridge. The peritoneal cavity of baby II was now opened in the same way.

The intestines were now packed off carefully, the packs being inserted along the surface of the peritoneal partition to reach the abdominal wall on the far side of the bridge. The nature of the peritoneal partition was now clear. Above, it was attached to the liver; and inferiorly it had a crescentic edge concave downwards. Its attachment to the near and far walls of the bridge extended down to the navel, and to its surfaces were attached the falciform ligaments. The upper part of this partition, just below its attachment to the liver, was now divided, together with the falciform ligaments. There was the expected plexus of veins in relation to the under surface of the liver and the falciform ligaments, but this gave less trouble than was expected. Care was nevertheless taken to clamp carefully the peritoneal folds of the liver before their division.

The Liver

It was now clear that the central part of the common liver could not be satisfactorily exposed for division until the bridge of cartilage which crossed from one chest wall to the other had been at least partly divided. It proved to take the form literally of a bridge or arch, being concave downwards in the coronal plane and forming a cartilage roof over the upper part of the common liver. It cut easily with the knife, but was really so rigid that it was surprising to recollect that the babies had been twisted through 90 degrees at birth. After the bridge had been divided to a point beyond its summit, the remaining cartilage on the far side yielded sufficiently for a much better view of the liver to be obtained. Care was taken not to distract the two infants from each other. It was felt that stretching of the liver after the loss of its cartilage protection might exert dangerous traction on the hepatic veins and on the diaphragm. The division of the cartilage did, however, give a much wider view of the presenting surface and of the inferior surface of the common liver, and the two gall-bladders could be demonstrated in the situations where cholecystography had shown them to lie. Obviously the next stage of the operation must be division of the liver through its centre in the bridge. No obstruction was met to a finger passed round the bridge to reach the lower edge of the liver on the far side.

At this stage of the operation it soon became clear to us how valuable was the method of liver control devised in Edmonton at the operation on the Townsend twins. In passing the forceps which would later guide the tourniquets round the liver bridge it was clearly desirable to keep as far as possible, on each side, from the centre of the liver. If the tourniquets lay too close together on the far side of the bridge they might easily slip through the cleft in the divided liver when liver division was completed. Consequently each artery forceps was induced to find its own separate way round the far side of the liver as far as possible from the median plane of the bridge. Each Penrose rubber drainage tube followed easily the path of its guiding forceps, and the tension made by this tubing when finally controlled by clip was very comfortable. It was estimated that the tourniquets lay 5 or 6 cm. from each other on the far side of the liver, and that there would not be much danger of their slipping when liver division was completed. It was found more convenient to divide the liver by knife and scissors than to tear through it with forceps, though the consistency of the liver varied from place to place: in one place it would be easy to tear through soft liver substances, while in another it was necessary to use sharp dissection.

When liver division had proceeded through approximately three-quarters of the bridge a thin band of liver tissue remained on the far side, and it proved easy to apply a Schumacher clamp and to divide the remaining liver between the clamps: though a variety of clamps were in readiness, this particular type was, as had been expected, the most suitable for the purpose. By rotation of the clamps towards the operator the raw surface of the liver of baby I could now be inspected. It was easy to distinguish open blood vessels and bile ducts, and these sustained the application of artery forceps surprisingly strongly without tearing. Indeed the impression was obtained that the divided vessels on the cut surface of the liver of this baby were easier to control than are those of the adult liver.

It had been intended to trim the cut surface of the liver to a concave shape so that its edges could be sutured together by stitches through Glisson's capsule, and the liver surface was inspected while consideration was given to this step. It was felt highly desirable to close the raw surface in this way lest bleeding should occur with the increase in liver flow which follows operation, and to avoid the oozing of bile into the peritoneal cavity, so commonly followed in babies by subphrenic abscess. In fact the question did not arise, for the liver tissue proved to be so flexible and elastic that the cut edge of Glisson's capsule on the far side of the raw surface could be brought quite readily forwards for suture. After division of the liver the abdominal contents had to be packed off again on each side to afford a view of the undivided peritoneum on the far side of the bridge. Division of the remaining cartilage link was now completed, and the soft tissues on the far side of the bridge were divided from within outwards.

Closing the Abdominal Wall

In closure of the abdominal wall a single layer of stitches was employed for muscle and peritoneum. In the upper part of the closed abdominal wound the heart could be seen beating through the opening in the diaphragm, where diaphragmatic muscle had presumably been united across the bridge under cover of the cartilage roof. That part of the cartilage bridge which now appertained to each child protruded in an unsightly way and had to be trimmed, but care was taken in trimming not to leave too much of the pericardial sac exposed. The procedure was now identical for the two children at the two separate tables except in so far as the liver of baby II had still to be sewn over after the moment of separation. The last stage in closure was to trim the skin over the hernia that had been present in the lower part of the bridge, and to excise on each side what remained of the hernial sac. The quality of the muscle in both babies was rather poor at this level, and the muscle closure at the lower end of the wound, though complete, gave rise to some doubt of its strength.

As separation approached completion the second team came into play. This proved to be really quite a complicated manœuvre. Its abdominal contents kept in place by packs and manual pressure, the baby, complete with transfusion apparatus, had to be carried to the second table, the anaesthetist moving over with his apparatus too. The manœuvre was completed without mishap.

It might be said at this point that all pre-operative predictions were, as has been seen, fulfilled as the operation proceeded, and the plan of the operation proved reasonably sound. There was, however, one fault in the planning which should be considered when this operation is repeated —the difficulty of an accurate swab count at the end of the operation which starts as a single operation and finishes as two operations performed by two separate teams. This did not occur either to the surgical or to the nursing planners until the time came to count the swabs at the end of the operation, when for a few minutes it proved extremely difficult to establish that no swab was missing.

The abdomen of the second baby was now closed, and the total operating time from the first incision to the insertion of the last stitch in the second baby was one hour and thirty-five minutes.

Thus at the end of the operation two apparently normal and separate babies were obtained. Their general condition was good, and the circulation of each was entirely satisfactory. The babies were in as good shape as any babies of that age are after an abdominal operation. The babies were returned from theatre to ward in a double oxygenaire specially constructed by the Oxygenaire Company to contain both. On their return to the premature baby unit, still in good shape, they were transferred to separate oxygenaires.

Collapse of Tomo

One hour after their return, while still under close inspection, Tomo suddenly collapsed. The chest was opened and the heart massaged for an hour. A ventricular rhythm returned but no normal beat. Post-mortem examination showed no cause for death. There had been no bleeding and the liver closure was perfect. There was no cardiac or other abnormality. The lungs were airless and oedematous, as is usually observed *post mortem* after artificial respiration with oxygen through tracheal tube and cardiac massage. The only possible cause of death lay in the adrenal gland. This was only about one-third of its normal weight as measured by the adrenal/renal weight ratio. It is possible that the surviving twin had been responsible in life for the greater part of the production of cortisone for the pair, and that the dead twin had insufficient adrenal-cortical tissue to withstand the shock of the operation. When this operation is done again it would be wise to give both twins cortisone, for usually in such a partnership one twin is dominant, providing more for, and taking more from, the joint organism. It is notable that after Holm's successful separation of twins conjoined only by skin, muscle, and cartilage one infant was noticed to be particularly pale and collapsed.

The Surviving Twin

The surviving baby's wound was well healed on the tenth day of her post-operative course (Fig. 7), and it gave rise to no anxiety whatever. There remained a weakness of the lower end of the wound, and this baby has the umbilical hernia which is exceeding common among Nigerian babies. There is a protuberance also where the cartilage bridge was divided, and this is to some extent due to the rather acutely sloping sternum, the children when joined having striven always to pull away from each other, a fact which led to distraction of the xiphisternum on each side forward in front of the upper part of that bone. *X*-ray examination of the surviving baby (Fig. 8) shows now dextro-rotation of the heart. But the electrocardiogram was not that of a situs inversus; there was therefore no true mirror-imaging of the twins present. The surviving baby and her mother left hospital to return to Nigeria on December 21, eighteen days after operation.

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