the fact, now sufficiently well observed, that in an otherwise healthy stomach ulcerative lesions produced by destruction of the mucous membrane quickly heal.

The gastric ulcers commonly met with clinically have very different causation in different cases; experimental work has shown that ulcers arise in the stomach in a variety of ways. In bringing the present observations before your notice I do not wish it to be thought that even a small proportion of clinical gastric ulcers are produced in this way. For this we must suppose a general or an intestinal infection or some such mechanism as Charles Bolton has so admirably worked out for a specific gastro-toxin. But we know rarely of the origin of ulcer in septicaemia, pyaemia, endocarditis, and a large number of other infective processes, both general and local, in which emboli or metastatic infective material may be brought to the stomach wall and produce an amount of necrosis of the mucous membrane that may give rise, after action of the gastric juice, to macroscopic ulceration.

In the instance here described we have a similar process. The spleen in the experimental animal, as in the human disease, shows a thrombo-phlebitis, as has been drawn attention to especially by Dock and Warthin in human cases of splenic anaemia. In some cases of the human disease this phlebitis is so massive as completely to obstruct the portal vein. In other cases, however, it is merely sufficient to thicken the efferent channels. The presence of thrombo-phlebitis in the splenic venules produces from time to time emboli which, travelling by the main splenic vein, are held up by the liver. That this is so is proved, first, by the evidence of what appear to be minute infarctions in the liver of the monkey. Unfortunately, I have so far not been able to get definite evidence of recent phlebitis in the radicles of the portal vein in the liver, owing to my desire to obtain as much material as possible for culture. But in Fig. 1, a section from the liver of a monkey the subject of a similar experiment, there is seen a localized area of phlebitis in a venule in the liver almost blocking the lumen. In this last experiment I have obtained a pure culture of the streptothrix from the spleen pulp.

On these grounds, remembering also that 30 per cent. of the splenic blood returns via the vasa brevia of the stomach, the assumption cannot be avoided that the same process evident in the liver is present in the stomach, a thrombo-phlebitis and inflammation of the neighbouring parts of the inner lining membranes of the stomach, with necrosis and consequent erosion by gastric juice of the area so affected. Histologically the gastric ulcers show the ordinary appearance of acute ulcer with a few minute thrombi in the veins of the periphery which might be seen in ulcer from other causes.

The lungs bear out the view of the presence of a shower of emboli leading to haemorrhages. We know that minute emboli are not stopped by having to pass through a capillary system, and the minute anatomy of the lung shows a marked degree of arteritis of the pulmonary arteries, with obliteration of their lumina (Fig. 2). The spleen in this case is atrophic and shows in a marked degree fibrosis and absence of Malpighian bodies, with phlebitis of the venous channels (Fig. 3). Patches of intense inflammatory reaction are to be found here and there. The difference between this and the spleen of a control animal may be seen by reference to Fig. 4, where the fibrosis is not evident and the Malpighian bodies of normal aspect may be seen.

In conclusion, I submit that in this experimental animal an inflammation of the spleen with thrombo-phlebitis has given rise to infective emboli, evident in their effects in the stomach, producing ulcers and haemorrhage, in the liver and lungs producing haemorrhagic lesions, and that in splenic anaemia, and more rarely in acholuric jaundice, the gastric haemorrhage may be due in a proportion of cases to septic embolism and consequent inflammation of the branches of the vasa brevia.

DISCUSSION.

Mr. D. P. D. WILKIE (Edinburgh) believed that the type of ulcer described by Dr. Gibson was probably that due to retrograde venous embolism. Attention was first directed to this type by von Eiselsberg, who suggested that the

haematemesis which occurred some days after abdominal operations in which portions of omentum had been ligated was due to the separation of a small portion of thrombus in an omental vein, the embolus thus produced being side-tracked into a gastric vein and arrested in the venous plexus of the gastric submucosa, causing there a zone of thrombosis, a devitalized portion of mucosa and thus an ulcer. Experimentally he himself had found that such a succession of events was possible, but in the human subject he had only met with two cases in which this appeared to be the cause of gastric ulceration. The cause of the ordinary peptic ulcer of the stomach and duodenum was now considered by most surgical pathologists to be due to arterial embolism, and the researches of Rosenow would indicate that streptococci borne by the blood stream from a primary focus in the teeth or tonsils were the causal organisms. Whilst he had failed in his efforts to confirm Rosenow's results experimentally he had repeatedly confirmed the presence of streptococci in such ulcers. The difficulty of isolating and growing on culture these strains of streptococci made the close co-operation of surgeon and bacteriologist a necessity in this line of investigation.

THE BONE GRAFT.*

BY

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THE bone graft is now universally recognized as a most effective means of bone repair and the most important modern development of orthopaedic surgery. The subject has been taken up with great keenness and enthusiasm by many, both from its practical and experimental aspects, with the result that the literary output has attained formidable dimensions.

The question of the part played by the bone graft remains undetermined, and Ollier and Macewen may still be considered as leading counsel for the claims of the periosteum and bone respectively. Both sides believe in the survival and growth of the graft, differing only in their interpretation of the process of its development. In England, Groves and Wheeler, while supporting Macewen in theory, are Franco-American in practice, as they advocate whole-piece, autogenous, periosteum covered grafts and rigid fixation. The success of the "inlay" technique and the claims of Albee, McWilliams and others seemed to silence all opposition until Murphy advanced the view that the graft was "osteo-conductive," acting as a scaffolding.

In July, 1918, in a short paper contributed to the BRITISH MEDICAL JOURNAL, I expressed the opinion that all that the graft did was to supply the biochemical stimulus or irritant which had been abolished by trauma or infection, the new bone being formed by the diaphyseal ends, by periosteal and bony remains in the shaft zone, and, in the young, by epiphyseal lengthening, and I supported Murphy's contention that the graft becomes absorbed. I adhere to that opinion, which has been strengthened by my recent work, the radiographic record of which shall be submitted to you.

I do not intend to weary you with lengthy descriptions of various histological and experimental observations, as they are mostly inconclusive and often contradictory. Suffice it to say that they veer in the direction of proving that growth—whether from periosteum, cambium or bone—is mainly subperiosteal, the rest of the graft showing atrophic changes.

We must admit that when a piece of tibia is used as a graft, logically speaking, we cannot expect it to grow, either in length, thickness, or density, to a greater extent than the parent bone, especially when we bear in mind the precarious nature of its blood supply. But it does grow, so we are told, and it grows by virtue of Wolff's law, which conveniently also explains the absorption of a graft when implanted in a region where there has been no bone before. In every contribution on the bone graft Wolff's law is the pivotal argument. Wolff has laid down the law and the bone conforms! And what is this law? It is nothing else than the universal law of organic strengthening under

* A paper read in the Section of Surgery at the Annual Meeting of the British Medical Association held in Newcastle-on-Tyne, July, 1921.

CASE I,

FIG. 1.—Tuberculous disease of radius with mixed infection.

FIG. 2.—Shows bone graft in the space of excised portion of diaphysis; drainage tubes used owing to profuse suppuration.

FIG. 3.—Shows active osteogenesis. Note loss of definition of the bone graft.

FIG. 4.—The completed radius.

CASE II.

FIG. 5.—Tuberculous disease of first phalanx of thumb.

FIG. 6.—Bone graft in periosteal sheath of excised phalanx.

FIG. 7.—Shows bone growth around graft, which is losing density in consequence of absorption.

FIG. 8.—The completed phalanx.

CASE III.

FIG. 9.—Whitlow of thumb, with necrosis of phalanges.

FIG. 10.—Bone graft equal in length to the excised phalanges *in situ*.

FIG. 11.—Note the vacuolation of bone graft and segmental reformation of the two phalanges (two months after operation).

FIG. 12.—Three months after operation. Disintegration of bone graft more marked.

CASE IV.

FIG. 13.—Myeloma of radius.

FIG. 14.—Tumour scraped out and transplant placed in cavity.

FIG. 15.—Invagination of bone graft by bone growth from shaft.

FIG. 16.—Commencing canalization of the reformed shaft.

stress and strain as seen in all plants, in muscle, and in bone. This is the law that is supposed to regulate the growth and shape of the bone graft.

The effect of stress and strain upon bone is undeniable. A fibula mobilized with its blood and trophic nerve supplies practically intact, and interposed between the epiphyses of a missing tibia, will thicken and in the course of many years may attain half the thickness of the missing bone. In speaking of the influence of Wolff's law we must retain therefore a sense of proportion. I am surprised that no one has attributed the shape and development of the bones of an embryo a few months old to intrauterine movements! The influence of this law is exaggerated, and the reasonings based thereon are unsound as far as the bone graft is concerned.

After a grafting operation a limb is immobilized for six, eight, twelve weeks or longer. We are all familiar with the condition known as disuse atrophy. A splinted limb wastes and there is wastage not only of the soft parts but actually of the bones, and Woodburn Morison of Manchester tells me that the degree of rarefaction and loss of density can be demonstrated by *x* rays. While the recipient bone is wasting in consequence of enforced rest, growth is claimed for the bone graft.

Albee, for instance, gives the following directions for after-treatment: (1) Place the limb in a position to relax displacing muscles; (2) immobilize the limb with plaster-of-Paris; (3) in desperate cases some support should be continued for three or four months. Obviously enough, his very directions are intended to abolish all stress and strain, and yet he speaks of firm unions and grafts acquiring the thickness of shafts in a few weeks' time. I do not question his results, but I question his interpretation.

Macewen pins his faith on the bone. His views may be summarized as follows: (1) Bone grows from bone; (2) the periosteum acts only as a limiting membrane. His famous case of the reconstructed humerus by the use of small homoplastic grafts is medical history. The patient was 2 years old. The epiphyses were not damaged. He considered the periosteum destroyed, planted his bones in the anatomical line, and attributed the formation of the new diaphysis to the growth and coalescence of his transplants.

I have had similar cases: flail limbs, soft limbs which showed no sign of bone formation for long periods, no vestige of bone in the line of the wound, but the radiographs revealed bone nests, numerous enough in some cases to indicate the alignment of the excised shaft. The absence of osteogenesis does not prove that the osteo-periosteal fabric is destroyed in its entirety—it never is—and should be considered as evidence of arrested or inhibited function. Furthermore, Macewen does not explain how he obtained limitation and growth to shape in the absence of a periosteal sheath.

The intramedullary graft has very few advocates nowadays. Here we have a transplant which can be applied with fairly easy technique according to the established canons: firm fixation, extensive bone contact, surface as well as medullary blood supply. Yet it fails, and fails because it induces pressure atrophy in the very shaft ends which are the main builders of the bony bridge, and because it obstructs the marrow from taking part in the osteogenetic process. Vacuolation and rarefaction can be seen around the penetrating segments. A non-rigid intramedullary graft (as the sliding graft in the femur) may succeed, a tight one never does. I am waiting for a satisfactory explanation from the Ollier-Macewen school of surgeons of the failure of the intramedullary graft.

Another noteworthy point is that sclerosed bone is not looked upon favourably for bone-grafting purposes. Thus Wheeler states: "In old and ununited fractures, with false joints, the bone near the critical area (near the seat of fracture) is sclerosed and avascular, and makes an unsuitable soil for that portion of the graft in contact with this area. Growth in the graft is impeded by the surrounding sclerosis, as dense sclerotic bone has no osteogenetic power." This statement is somewhat contradictory, as he expects growth both from the graft and the shaft end. If the graft were capable of a separate existence it should live even though its connexions with the diaphyseal ends were fibrous. But in my experience the sclerosed bone does respond, granted that the graft is not under pressure

and growth in length is always from the proximal stump. Singularly enough, the same condensation of bone is seen at the attenuated end of the lengthened proximal segment.

The explanation is that on the introduction of a transplant two forces are evolved, acting simultaneously—the osteoblastic and the osteoclastic. If the former exceeds the latter in degree, the shaft is completed before the graft is absorbed, and, contrariwise, you may have the reconstructive process little advanced when the graft disappears from the field, the osteoclasts being the dominant force. As a rule, active osteogenesis is seen in the proximal and osteoclasts in the distal sector.

The appearance of callus on a broken graft has been hailed as proof of the survival of the graft. I look upon it as evidence of greater local stimulation. I may say at this juncture that I consider the periosteum as possessing stimulating properties of a high order, and I believe that before long the Delaginière technique will take the place of the exquisite joinery we are all disposed to practise at present.

There is no limit to the resourcefulness of the enthusiast, Albee's grafts always live and functionate, and when he discovers that his transplants of compact bone become cancellous in the spine, he sticks to his guns with some show of power, and his final salvo is the explanation that the bone graft is capable of histological as well as morphological adaptability. In Pott's disease the patient is splinted, but, more important still, there is intense muscular spasm of a reflex order; there is voluntary rigidity as a result of what may be termed kinophobia (fear of movement). The cry is for fixation, for compact bone. There is no physiological demand for this metaplasia. The cancellous bone originates from the spinous processes. Delbet, on the other hand, sees his graft unaltered in a cancellous environment. His peg of compact bone lives in the neck of the femur for years without change, as many a screw does. I still maintain that if a graft remains identifiable for six months or longer the case is one of necrobiosis.

Faith in the immortality of the graft has produced its corollary in the shape of a belief in its power to resist infection, and this has met with general acceptance. Everybody says it, but no one with less ambiguity than De Courcy Wheeler: "The bone graft has inherent bacteria-resisting properties." What is really meant is that a piece of bone in anatomical and physiological isolation is a bad culture medium. True, the graft does play its part in the presence of sepsis—not owing to its inherent bacteria-resisting properties, but because the concomitant infection is *per se* a stimulant to bone-forming structures.

A zone of new bone—an involucrum—is thrown out in almost every case of osteomyelitis, but this reaction is absent in tuberculous and neoplastic diseases of bone, as these are not only purely destructive processes but actually osteo-depressant. The consolidation of a grafted ununited fracture in the presence of infection illustrates a type of union brought about by two stimulating agencies, the graft and the infection.

I agree with Heitz-Boyer and Scheikevitch that Texier's method of securing bony ankylosis by introducing mild infections into flail joints is a measure deserving of serious consideration in the treatment of these cases. But I go further, and I say that the cellular activity resulting from the implantation of a bone graft has a marked inhibitory effect on all infective processes, and to this I attribute the fact that throughout my experience with the bone graft, and particularly during the war—with infection lurking beneath every scar, with tissues devitalized by and studded with shrapnel—I have not lost a patient, I have not had to amputate a limb, nor have I seen a case of virulent infection, though medullary cavities and Haversian canals were gaping open, seemingly ready for any catastrophe. Encouraged by this lesson, I have never hesitated to insert grafts in the presence of mild and, recently, actually of acute infections. This is demonstrated in the radiograms.

Case 1 (Fig. 1) was a case of tuberculous disease of the radius, with mixed infection; the skin was riddled with sinuses. In Fig. 2 the bone graft is shown in the space of the excised portion of the diaphysis; the excellent splinting effect of the transplant and the maintenance of correct alignment may be noted; scales of bone are still adherent to the periosteum, and there is a tuberculous cavity in the proximal diaphyseal stump. In Fig. 3 active osteogenesis

is demonstrated; the loss of definition of the bone graft should be noted. Fig. 4 shows the completed radius.

Case II (Fig. 5) was a case of tuberculous disease of the first phalanx of the thumb. Fig. 6 shows the bone graft in the periosteal sheath of the excised phalanx; it should be noted that the articular cartilages have not been interfered with. Fig. 7 shows bone growth round the graft, which is losing density in consequence of absorption. In Fig. 8 we have the completed phalanx.

Case III was a whitlow of the thumb with necrosis of the phalanges. In Fig. 9 there may be observed the enormous swelling of the soft parts owing to virulent suppuration and poulticing. Fig. 10 shows the bone graft, equal in length to the excised phalanges *in situ*. In Fig. 11 there should be noted the vacuolation of the bone-graft and segmental reformation of the two phalanges (two months after operation); suppuration has greatly diminished and the soft parts are acquiring a normal outline; there is good movement at the metacarpo-phalangeal joint. Fig. 12, three months after operation, shows disintegration of the bone-graft more marked; the thumb is almost normal in appearance, the sinuses have healed up, and there is improved movement at the metacarpo-phalangeal joint. This case is still under observation.

Case IV was a myeloma of the radius; in Fig. 13 the osseous outline of the growth may be noted. In Fig. 14 the tumour is scraped out and the transplant placed in the cavity; there is an "inlay" contact with the healthy end of the shaft. In Fig. 15 invagination of the bone graft by bone growth from the shaft is demonstrated; ossifying lamellae in the "egg-shell" cavity should be noted. In Fig. 16 is shown commencing canalization of the reformed shaft; it should be observed that bone of normal density occupies the space originally filled by the growth.

I am satisfied that the new bone and cellular life generally which result from the stimulating effect of the transplant are capable of overcoming pyogenic and tuberculous infections (Cases I, II, III) and of reviving normal osteogenesis in bones affected by neoplastic formations of low malignancy (Case IV).

My thanks are due to Dr. Woodburn Morison of Manchester and Dr. Brice of Dukinfield for the radiograms.

GENERAL ANAESTHESIA AND THE ATMOSPHERE IN THE OPERATION THEATRE.

BY

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In 1908¹ a note was published on the administration of ether by the open method in which the possibility of using a valved container was described, the valves being placed between the container and the face-piece. This was in the early days of "open" ether. Since that time the adoption of Hewitt's principle of using wide-bore tubes, which tends to abolish stimulation of the respiratory effort and so to lessen stridor and cyanosis, and the provision of a larger evaporating surface for the ether, have given us various pieces of apparatus for the same purpose. One of the best known of these is the Anson and Caldwell-Smith inhaler. Such an apparatus produces as good an anaesthesia as is obtained by the true open ether method, and at the same time considerably lessens the loss of the drug due to direct evaporation into the atmosphere. In any such piece of apparatus at first about 50 per cent., and, when anaesthetic equilibrium is established, 100 per cent. of the ether used is discharged into the theatre. In fact, at the present time it is not unusual for those engaged in operative work to be surrounded by unpleasant and deleterious vapours which would neither be tolerated nor permitted by law to exist in any ordinary factory. The chief sufferer is the anaesthetist, and next to him the surgeon and those in greater or less proximity to the patient's head. Some persons are more readily affected than others. As later results gastritis and anaemia are not unknown. In field work and in some cases where small rooms are used the effect on the staff is

serious. This is notably the case when a flame, a glowing fire, or an electric heater is exposed to the vapour of chloroform, which is transformed into phosgene gas, and is one of the main reasons why operation theatres are heated by steam or water piping. In small and repeated doses this gas produces anaemia. In larger doses it leads to a feeling of tightness and constriction in the chest, most marked about twelve hours after the exposure, and followed by bronchitis of a varying degree of severity.

The "open" ether method, especially when combined with the use of narcotic and other drugs, is very safe, a fact which has undoubtedly had great weight in causing its almost universal adoption as an anaesthetic of choice for the great majority of operations.

We have thought for some years that it ought to be possible to generate the vapours outside the theatre entirely, to deliver them to the face-piece through a wide tube and to remove them by a similar channel, so that the atmosphere of the theatre need never be materially contaminated. One of us (G. H. C.) mentioned the point to an anaesthetist in 1907, but the matter did not materialize. We are not at present proposing to experiment in this way on any large scale, but we wish in this preliminary note to mention the chief points which seem to us important and which will undoubtedly require consideration in theatre construction in the future, as our trials demonstrate. In this way we hope to interest others who are conversant with the varied conditions existing in different parts of the country. It may be noted that the principle of removing the source of anaesthesia to a distance has been put into practice for some years past in cases in which a preliminary laryngotomy or tracheotomy is performed and the tube connected to a distant "tambour."

At the outset there will be a difference in plan according as to whether the operation is to be performed in an operation theatre or elsewhere. In the case of a theatre a permanent plant could be established just as illuminating gas is laid on. From the generator the tubes would be brought through the floor near the table, with taps, unions, and flexible connexions there, so that the apparatus suitable to the case could be connected to the main supply and exhaust. In some cases a single generating station might be arranged to supply to and exhaust from several theatres. But when the operation is to be done in a private house a portable apparatus would have to be employed and adapted on arrival to the local conditions. This could be made a simple thing, as we propose to show.

In the second place, the source of ether vapour should not allow any loss to occur to the outside air, partly on the ground of expense and partly to avoid contaminating the atmosphere near the theatre, bearing in mind the ever-present risk of explosion from a spark from an electric motor or other cause. To ensure this it would be necessary to generate the vapour at some distance from the air entrance, and perhaps to put a valve stop and fine wire gauze mesh behind it. The strength of the vapour could be regulated by a tap or throttle or other contrivance controlled from the operation table.

Thirdly, there should be a heater for the vapour and a quick-movement thermometer in the face-piece to show the temperature at which the anaesthetic vapours reach the patient. The face-piece itself would comprise an inlet and an outlet valve, but these might be provided for elsewhere and at a distance if found more convenient and if the CO₂ content of the system were not too great. In case any friction should arise in the system it will be necessary to maintain an exhaust at the exit of the fairway of such a degree that the valves would act with the minimum of differential pressure, and so that there would be hardly any deviation from atmospheric pressure inside the face-piece.

Fourthly, it will be necessary to arrange for the delivery to the fairway of nitrous oxide, ethyl chloride, chloroform, oxygen, or other agent as required, and the apparatus should preferably be adaptable to intratracheal methods.

Lastly, the expired vapours should be trapped in a suitable solvent from which the chief ingredients could be recovered by distillation or otherwise.

It seems to us that this proposal is the ideal that will have to be taken into account in the future in the construction of any operation theatre, and that its adaptation to existing theatres will only be a matter of time. There is little doubt that the initial outlay would soon be wiped out by the saving of the cost of the drugs recovered.