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The Classic

Symposium on Arthroplasty*
Arthroplasty: Experimental and Clinical Methods

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Abstract This Classic article is a reprint of the original work by Nathaniel Allison and Barney Brooks, Symposium on Arthroplasty: Arthroplasty: Experimental and Clinical Methods. An accompanying biographical sketch of Nathaniel Allison, MD, is available at DOI 10.1007/s11999-009-1121-2. The Classic Article is © 1918 by the Journal of Bone and Joint Surgery, Inc. and is reprinted with permission from Allison N, Brooks B. Symposium on arthroplasty: arthroplasty: experimental and clinical methods. *J Bone Joint Surg Am*. 1918;s2–16:83–93.

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Experimental Methods

The amount of experimental work on the mobilization of joints in animals is relatively small. The amount of experimental work which has been done on human beings is, unfortunately, very large indeed. In this paper it is particularly the knowledge which had been gained from experimental animal work which will be considered. The discussion will be limited to the methods which have been used within the joint cavity. It is realized that a joint may be made perfectly stiff by changes in and about the capsule, but in the great majority of cases, the most important changes are within the joint capsule, and have to do with the joint surfaces. In other words, only the work bearing on the mobilization of ankylosed joints by the interposition method will be considered.

The experimental work will be reviewed under three divisions according to the character of the material interposed.

I. Living tissues, i.e., the pedunculated or free transplants or fascia, muscle, fat, tendon, or peritoneum.
II. Non-absorbable foreign bodies, i.e., silver foil, gutta percha, magnesium plates, etc.
III. Absorbable foreign bodies, i.e., chromicized pig's bladder of Baer, and silver impregnated fascia of Brooks and Allison.

Experimental Work with Living Tissues as Interposition Material

In 1905, J. B. Murphy reported two experiments on animals. The hip joint surfaces were destroyed and broad flaps of fascia and fat were interposed. From dissection and microscopic study he believed the interposed tissue led to the formation of a sort of a new joint cavity which he called a bursa. Subsequently his assistant, Neff, reported four experimental arthroplasties by the same method and came to similar conclusions. Putti and Davis have reported experiments in which fascia was transplanted into joints. They found that the transplanted fascia remained viable and preserved its normal histological characteristics.

Brooks and Allison have reported experiments in which free and pedunculated transplants of fascia were used in joints after destruction of the normal joint surfaces. They found that there was no essential difference in the results following the use of the free transplant and the pedunculated transplant. In some cases the transplants remained in whole or in part viable and preserved the normal histological characteristics, while in others the transplants degenerated. They found that the union of the joint surfaces was prevented in the cases in which the transplants degenerated and were absorbed.

Kolaczek reports five experiments in which a portion of the knee joint capsule in dogs was excised and the defect in the capsule was repaired by homo-transplantation of peritoneum. The joint cartilages were not injured. The animals were observed for periods of 15 to 47 days. It was found that the transplant healed in the defect and formed no adhesions to the joint surfaces. From these observations, the author suggests the possibility of using transplants of peritoneum in arthroplasties for the mobilization of ankylosed joints.

The most careful and comprehensive experimental work on the use of living tissues for interposition material in joints is that of Sumita. Sumita reports twenty experiments very carefully observed. The method consisted in the destruction of the joint surfaces of the knee, hip, and ankle joints of dogs, and the interposition of pedunculated flaps of muscle, fat and fascia, and tendon. The animals were allowed to live for periods of 21 to 244 days. The experimental joints were studied by x-ray examination, dissection, and microscopical examination. In no cases was there observed to be ankylosis by bone, and all joints so treated allowed passive motion. It was found that the interposed living tissues underwent degeneration or conversion into fibrous tissues. In this fibrous tissue between the ends of the bones, small cavities were found. These cavities were believed to be the result of hemorrhage into and degeneration of the living tissues interposed. Great importance is attached to the formation of these cavities. It is interesting, however, to note that in only one experiment is a cavity as large as 1½ cm. in diameter mentioned, and this finding is punctuated by exclamation points. The cavities found in other experiments were only a few millimeters in diameter or even microscopic.

Bearing particularly on this work are the experiments of Allison and Brooks on experimental ankylosis, and those of Leonard Ely on the results of simple resection of the knee joint in dogs. Allison and Brooks destroyed the joint surfaces of the knee joints in eleven dogs, by scraping away the articular cartilage, by a resection of the joints, or by direct infection of the joint cavity. The joints were closed without the interposition of anything. The animals were allowed to live for periods of 6 to 334 days. In only one experiment was actual ankylosis by bone found. The other experimental joints all showed fibrous union with varying degrees of joint motion. Moreover, the same small cavities described by Sumita were found in such joints. These were believed to have been formed from portions of synovial membrane not removed at operation. Ely reports the results of excision of the knee joint with no interposition of substances, in 19 dogs. The animals were allowed to live for periods of 14 days to 2 years. In this series only 2 joints became ankylosed by bone; one in 88 days, the other in 432 days. The one case in which bone ankylosis occurred in 88 days should not be considered, as it followed the excision of the entire epiphyses of the femur and the tibia and the approximation of the shafts of these bones. Ely also found cavities between the bones, and believed that a complete regeneration of a new joint cavity was possible. The one experiment (Dog No. 7) in which the author describes the formation of a large true joint cavity is clearly a mistaken observation, as the illustration shows that joint surfaces were not destroyed in the operation. From the observation that motion persists after resection of the knee joint in the interposition of substances, Ely concludes that all experimental animal work on arthroplasty with the interposition of material in the joint, should be thrown out. This is obviously a false conclusion, as the same thought would result in the author's recommending resection of the joint as a treatment for ankylosis. As a matter of fact, experimental work on arthroplasty by the interposition method has led to the discovery of very important facts.

Hohmeier and Magnus report a series of experiments in which they found that following the resection of dogs' joints, with or without interposition of living tissues, the same end-results were obtained.

To summarize: Experimental study of arthroplasty with the interposition of living tissues has shown that the tissue interposed undergoes more or less complete degeneration or substitution by fibrous tissue. In this process there may result the formation of small cavities. There is no evidence whatsoever of the reformation of anything like a *normal* joint cavity. The end-results of the destruction of joint surfaces and the interposition of living tissues in animals has not differed materially from the end-results of simple destruction of the joint surfaces without the interposition of any material.

Experimental Work with Non-Absorbable Foreign Bodies as Interposition Material

Very little experimental work has been done on the interposition of non-absorbable foreign bodies, and the idea is, in the light of present knowledge, so much discredited, that it will be dismissed with the statement that silk, plates of magnesium, silver, gutta percha and other things have been tried and discarded.

Experimental Work with Absorbable Animal Membranes as Interposition Material

The first to recommend and use extensively an absorbable foreign body as interposition material in the treatment of ankylosed joints was W. S. Baer. Unfortunately the author has not reported in detail his experimental work on animals. From his clinical publications it seems that his fundamental idea is that the chromicized pig's bladder membrane is placed in the joint for the purpose of preventing the union of the joint surfaces by bone or fibrous tissue. It is stated that the substance remains intact for a period of about 40 days, after which it is sooner or later completely absorbed.

Allison and Brooks reported a series of experiments in which various substances were used as interposition material in experimental arthroplasty. The duration of the persistence of the materials was determined, and special attention was given to the reaction of the tissues to the presence of the interposed material. It was found that Cargyl's membrane persisted between the opposed joint surfaces only for a few days, and did not prevent the adhesion of the opposed joint surfaces. Chromicized pig's bladder membrane persisted for a longer period of time, but it was found that the reaction of the surrounding tissues was of such an intensity that even at the time the membrane was disintegrating there was formed adhesion between the granulating surfaces. It was found that fascia which had been fixed and impregnated with silver remained intact between the denuded joint surfaces for about thirty (30) days and that it caused relatively little reaction in the surrounding tissues. The silver impregnated fascia was completely absorbed and the adhesion of the opposed joint surfaces was prevented.

To summarize the knowledge which has been gained from experimental work and point out the practical importance of some of the most important known facts:

First, and most important of all, animal experiments have proved, beyond all question of doubt, that such assertions as "The production of new joints is not difficult technically," or "Perfectly movable normally functioning joints with sliding rotary motion of the normal type can be And have been produced" are not true. Experimental work has also demonstrated another fact, the full appreciation of which should be the foundation of all attempts at arthroplasty. This is that joint surfaces adhere to each other in the same manner as other surfaces in the body ^and that joint cavities are obliterated in the same manner as cavities elsewhere in the body, viz., by the proliferation of inflammatory tissues. The union of joint surfaces is always first fibrous, and actual bone develops very slowly indeed, only after months, or even years. The growth of new bone from the epiphysis is a negligible factor in the treatment of ankylosis. The interposition of material in joints should be with the idea of the prevention of the adhesion of the surfaces by fibrous tissues, and not with the idea of preventing ankylosis by bone. This, we believe, indicates that the ideal substance for interposition material is an absorbable substance which would cause no inflammatory reaction and which would persist in the tissues until the stage of active granulation tissue production has ceased.

The substance which has seemed to approach most nearly these requirements is silver impregnated fascia. Baer's chromicized pig's bladder is absorbable and persists in the joints for the proper length of time. However, it causes more reaction in the tissues than the silver impregnated fascia.

As to the method of preparation of this fascia it suffices to say that the living fascia is immersed in the solution of silver nitrate until it is hardened, and then the silver nitrate absorbed by the fascia is reduced to metallic silver. This gives a sterile, pliable, thin, non-irritating membrane. The reasons for the addition of the silver are:

1. It has been shown that metallic silver has definite inhibitory powers both on the growth of organisms and tissues.
2. The method of fixation is such that the membrane is always perfectly sterile.
3. The fixative, which is of necessity an irritating chemical, is entirely destroyed.

In our own experimental and clinical work we have used the fascia lata from the animal or patient in which the arthroplasty was to be done. The fascia has been removed by a preliminary operation, fixed and impregnated with silver, and used later in the arthroplasty. Recently, the commercial preparation of this fascia has been undertaken by the Hollister-Ashland Laboratories, Chicago, and animal experiments are now in progress to determine the results of the use of this commercial product.

Clinical Methods

The attempt to reestablish motion in a stiff joint in the human being has for a long time appealed to surgeons. Many and diverse methods have been used. No method has as yet given satisfactory results. The means which have been used are briefly as follows:

1. Repeated forcible manipulation of the stiff joint.
2. Production of a pseudarthrosis in the region of the ankylosed joint.
3. Resection of the joint.
4. Arthrolysis followed by simple closure of the joint.

5. Arthrolysis followed by placing the ends of the bones in a position of dislocation for a short period and then replacing them in the normal position.
6. Complete excision of the joint, followed by transplantation of the entire joint from another individual.
7. Arthrolysis with the interposition of various substances between the joint surfaces.

The attempt to reestablish motion in a stiff joint by forcible manipulation dates back to the earliest period of surgical treatment. At the present time, this method is still in use. There are few instances, however, in which success has followed its use, and the rule is that the joint progresses to complete ankylosis in spite of oft-repeated manipulation treatment.

The production of a pseudarthrosis in the region of an ankylosed joint was probably the first open operative attempt to reestablish function in a stiff hip. In 1826, at the Pennsylvania Hospital, Ehea Barton divided the neck of the femur in a case of hip joint ankylosis and corrected a deformity. The operation was followed by non-union, and the patient lived for six years and had a good weight-bearing leg with some motion in all directions at the hip joint. This operation was performed again in 1830 by Rogers of New York with even more satisfactory results.

Berard, Esmarch, Rizzoli, Verneuil, and McIlhenney devised similar operative methods for the treatment of ankylosis of the temporo-maxillary joint. Richet also used this operative method in the treatment of various ankylosed joints. He advised the covering of the ends of the divided bone by flaps of periosteum to prevent subsequent union.

For obvious reasons this method of treatment is not to be recommended even if a pseudarthrosis could always be produced.

The actual resection of the ankylosed joint, with the idea of obtaining a flexible fibrous joint, has been used in the treatment of ankylosis of the jaw, elbow, and hip, with good functional results in a certain proportion of cases. It is worth while emphasizing that many so-called arthroplasties are in reality joint resections.

Simple arthrolysis, in which the ankylosis is broken up and the joint surfaces made smooth, followed by closure of the joint, has been extensively used in the treatment of ankylosis. Wolff has reported nine cases operated on by this method and claims good results. Von Eiselsberg reported two cases treated in this manner with one good result and one poor result. As a rule, cases operated on by this method are unreported.

Kocher suggested in the operative treatment of ankylosis of the knee joint, that after arthrolysis the joint be put in a state of dislocation for short period, and subsequently the dislocation be reduced. There is nothing in the literature which indicates success following such a procedure.

Lexer has excised the entire ankylosed joint and transplanted into its place the entire joint of another individual, the transplant being obtained from a recently amputated leg or from an individual soon after death. Satisfactory results have not followed the use of this formidable procedure.

Arthrolysis followed by the interposition of various substances between the joint surfaces has come to be the most widely used method of treatment of ankylosis of joints. This method has given the largest proportion of improved cases, and as operating surgeons appreciate more clearly the pathology of the process of joint ankylosis and the macroscopic and microscopic changes which occur in the tissues following the interposition of various substances in joints, the possibilities and limitations of the interposition method will become more clear and the results of the use of the method will improve.

Various kinds of substances have been used as interposition material. Carnochan, of New York, in 1840, interposed bits of wood and cotton in the attempt to reestablish motion in an ankylosed jaw. Orlow, Roser, Chlumsky, Hoffa and others have used various sorts of inorganic nonabsorbable material, such as plates of magnesium, silver, gold, celluloid, zinc, rubber, etc. The results, however, of the use of non-absorbable inorganic material have been such that it has been almost completely discarded. The material which is now used almost universally is either free or pedunculated transplants of living tissue or implants of an absorbable organic substance.

Verneuil in 1860 successfully used a piece of muscle and fascia as interposition material in the treatment of an ankylosed jaw. Helferich in 1894 first brought this operation to general notice, and Richet, Nelaton and others soon applied similar methods in the treatment of ankylosis of other joints. Murphy in 1904 increased the general interest in this country as to the possibilities of reëstablishment of motion in ankylosed joints by the interposition method by reporting good results in 12 cases operated on by him. Murphy advocated the use of pedunculated transplants of fascia and fat. In Europe, Payr has been the chief exponent of this method of treatment. He has devised several very ingenious procedures. He uses large pedunculated flaps of muscle, fat and fascia. He, particularly, has emphasized the importance of removing a large amount of bone.

Following the demonstration by Kirschner that free transplants of fascia remained viable, many operators have used free pieces of fascia as interposition material. Payr states that he did not get as good results after free transplantation of fascia as those which followed the use of the pedunculated transplants.

W. S. Baer was the first to use an absorbable animal membrane. He states that the use of a pedunculated

transplant of living tissue is often followed by a painful, unstable joint, and he has reported good results following the use of his animal membrane in various joints. Baer's animal membrane is obtained by the hardening of pieces of pig's bladder in chromic acid and subsequent sterilization by boiling in kumol. This substance is absorbed after a period of about 40 days. It is a thin, relatively pliable substance which can be adjusted to fit in the joint cavity and separate the denuded joint surfaces.

Allison and Brooks have used as interposition material a specially prepared fascia. It is a thin, pliable membrane which heals into the joint cavities with little local reaction, and which is absorbed at the end of a period of about 30 days. They emphasize the non-irritating qualities of this animal membrane.

At the present time, we believe there is no longer question that the interposition method is the best method of treatment of joint ankylosis. The kind of material interposed, the operative technic, and postoperative care are still matters for discussion.

The viewpoint of those advocating the use of living tissue is expressed by Neff in the following manner:

"From even a superficial study of the theory of operation and of the various methods proposed to produce permanent and useful motion in ankylosed joints, two points are clear: The first is that a pad of connective tissue must be present between the bone ends before the bursa or new joint can be formed; and the second is that the simplest, quickest, and most direct way of accomplishing this must be the method of choice. This being the case, there can be no doubt that the interposition of joint capsule or a flap of fascia, either pedunculated or free, constitutes the ideal operation of arthroplasty."

Baer has stated that it is his belief that the success of the operation depends on the character of the membrane used. He enumerates the following requirements:

1. It must be absorbable.
2. It should remain unabsorbed for 30–40 days.
3. It should be pliable enough to mold itself to the joint surfaces and cover all denuded surfaces.
4. It must have strength enough to permit it to be held firmly in place by sutures.
5. It must be sterile.

Our own beliefs as regards the character of the substance best suited for interposition material in arthroplasties agree with these requirements as stated by Baer, except we emphasize the fact that the substance used must have the least possible irritating properties.

The views of those advocating the use of living tissue and those advocating the use of an absorbable non-living substance as interposition material can be briefly stated as follows:

The former interpose the living tissue between the ends of the bones with the expectation that a new joint cavity will develop as a result of certain degenerative changes within the interposed tissue, and the latter interpose an absorbable non-living substance between the joint surfaces, with the idea that it will preserve the cavity created in the operative procedure. We believe there is little experimental or clinical evidence that anything approximating a normal joint cavity develops as a result of degenerative changes in living tissue interposed between joint surfaces. The small cavities which form may serve to increase the range of motion following the use of living tissue as an interposition material in operations on the hip or the elbow, as the small cavities which form between the ends of the bones in an ununited fracture probably increase the range of false motion of the fragments; but we do not believe this method ever results in the formation of a joint cavity which permits of the sliding motion necessary to the normal function of a knee joint. On the other hand, we believe that experimental work on animals has shown conclusively that union of approximated denuded joint surfaces may be permanently prevented by the interposition of a non-irritating absorbable animal membrane.

Time does not permit the consideration of the application of operative methods to individual cases, but, briefly, the operative method which has seemed best consists in separating of the ankylosis in a manner to produce joint surfaces which conform as nearly as possible to the original joint architecture, and placing the absorbable animal membrane so as to separate all opposed denuded joint surfaces. In operations on the hip joint, the lateral curved transverse incision, followed by the temporary removal of the great trochanter, has seemed to be the best method of exposing the joint. In operations on the knee joint the method of exposure which has seemed best consists in an anterior longitudinal incision, followed by a longitudinal splitting of the patella and tendons. The ankylosis is then broken up and the joint surfaces are exposed by marked hyperflexion of the knee. This method gives a good exposure and does not harm any of the vital holding structures of the joint. The method described by Payr, of temporary removal of the tibial tubercle and reflection of the patella and tendon upward, gives a very excellent exposure. It has been used in a few of our cases, but we have discontinued it for the reason that it seems desirable for the patient to begin active and passive motion of the joint as soon after operation as possible. This is before the time we have felt safe in risking the union of the replaced tibial tubercle. In operations on the knee joint the removal of a large amount of bone is not advisable, for the reason that subsequent instability may result. A rigid knee joint is preferable to one with good motion and poor stability. In operations on the elbow, the joint has been exposed by a

posterior longitudinal incision through the triceps muscle and tendon.

As regards the post-operative care of the patients, it is to be emphasized that every patient must have very careful supervision for a long period of time. After operation the patients should be encouraged to begin active motion of the joint as soon as the operation wound is healed. In the case of the hip joint this is at the end of 4–6 weeks, but in all other joints active motion should be begun at the end of 10–14 days.

No joint should ever be moved actively or passively to the point of causing pain or inducing visible local inflammatory reaction. Repeated baking and massage must be continued as long as there is any indication of increase in joint function.

In conclusion it is to be emphasized that the results of all known operative methods for the relief of joint ankylosis are at best most often unsatisfactory. In general the hip, elbow and jaw results are fairly good. The results of arthroplasties on the knee joint are the least satisfactory. Every patient should, previous to operation, be clearly and frankly as possible told of the impossibility of restoration of complete normal joint function, and that the most he can hope for is improvement after a long and tedious treatment.

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