The History and Development of Syme's Amputation

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JAMES SYME (1799-1870), the last and greatest of the pre-Listerian surgeons (Fig. 1), was renowned in his day as the most eminent surgeon in the English-speaking world. Well informed and well trained by study and travel, he developed in practice the experience, courage, sagacity, and dexterity that enabled him to obtain improved results in the surgical treatment of disease at a time when anaesthesia and antisepsis were unknown. During his occupancy of the Chair of Clinical Surgery at the University of Edinburgh (1833-1869), he developed and perfected many new surgical procedures. Time has outmoded them all save one—his disarticulation amputation through the ankle joint with preservation of the heel flap to permit weight-bearing on the end of the stump.

In the days before antisepsis, the surgeon's efforts to cure his patients frequently ended in disaster. Compound fractures and operation wounds were almost invariably complicated by one or other of the "hospital diseases" *(14)*: erysipelas, septicaemia, pyaemia, hospital gangrene. The patient was fortunate if he escaped death. On rare occasions his wound might heal by "first intention" or "under a scab." Otherwise the wound became "inflamed." If it discharged "laudable pus," it might heal by "second intention," and if so the outlook was reasonably good. But if the discharge was "thin, watery, sanious, acrid," the future for the patient was ominous. Death too frequently supervened. We know now that these complications were the manifestation of virulent infections. But in 1843, when Syme wrote his first paper *On Amputation at the Ankle Joint (30),* Pasteur's work on fermentation *(41),* which first revealed to us the world of microorganisms, was still more than a decade in the future (1856), and Lister, the founder of antiseptic surgery, was at age 16 finishing his preliminary education with a view toward entering University College, London. Twenty-four years were to elapse before Lister first wrote on his success in treating compound fractures with carbolic acid (1867). Till then the surgeon resigned himself, as had his predecessors from the dawn of history, to the possibility that his most skillful efforts and even the most simple of his operations would be followed too often by dangerous or even fatal reactions. Writing of this period, Volkmann *(14,44)* said in flowery simile:

> The surgeon is like the husbandman, who having sown his field, waits with resignation for what the harvest may bring, and reaps it, fully conscious of his own impotence against the elemental powers, which may pour down on him rain, hurricane and hail storm.

There is a vivid and moving picture of the surgery of the preanaesthetic and preantiseptic era in the story *Rab and His Friends (6).* The author, John Brown, was Syme's pupil and later his colleague and friend, and he admired him profoundly. In the memorial he wrote after Syme's death, he stated (7):

> He was my master—my apprentice fee bought him his first carriage; a gig, and I got the first ride in it, and he was my friend. He was I believe the greatest surgeon Scotland ever produced; and I cannot conceive of a greater clinical teacher.

In the account of Ailie's operation, in *Rab and His Friends,* Syme is the surgeon, and John Brown is the house surgeon who tells the story. In spite of Syme's skill in removing Ailie's breast for cancer, she develops sep-

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Fig. 1. James Syme (1799-1870), Professor of Clinical Surgery, University of Edinburgh, 1833-1869. Holl's engraving from George Richmond's drawing of him "in the prime of life." Probably this was Syme's likeness at age 43 when he performed his first amputation at the ankle. From Paterson *(25).*

ticaemia and dies. The agony of her death from this frequent complication of the surgery of those days is so graphically depicted that it brings home to us with dramatic force the immense risks which beset the individual who sustained a compound fracture or was compelled to submit to surgical treatment—all the more impressive because it is told to us by a participant in the tragedy.

In the case of open fractures, the complications were so likely to be fatal that the most radical measures were deemed necessary to forestall the spread of "putrefaction." Immediate amputation through the thigh was the standard procedure for compound fractures of the tibia and fibula, amputation at the site of election (a hand's breadth below the tibial tubercle) for caries and compound injuries of the foot *(30,31,32,33,35,36).* Though the mortality from these amputations was 25 percent in the hands of the best surgeons and 50 percent in hospitals less carefully managed *(14),* the results were better than those to be had from any other form of treatment. The result of conservative treatment was much worse. Mortality from compound fractures of the femur so treated was 80 percent *(14),* from compound fractures of the tibia 50 percent *(14),* and from compound dislocation of the astragalus 87 percent *(32,36).* Whether patients

were treated conservatively or by amputation, the mortality from compound injuries of the foot was shockingly great. Of those who survived compound dislocation of the astragalus without amputation, Syme said *(32,36):*

> . . . the foot generally remains in such a state of stiffness, weakness and sensibility to external impressions as to be rather an encumbrance than a support to the patient.

For those who survived after amputation of the leg, the disability from loss of the limb also was great. In the words of Syme *(32,36)*:

> So long as the only alternatives were an attempt to preserve the limb and amputation of the leg, there was a strong inducement to abstain from operating. But if the patient's safety and speedy recovery may be ensured by taking away merely that part of the limb, which in the circumstances can be of little value either to use or ornament, while at the same time a stump is produced in all respects preferable to a shattered, stiff, irritable foot, I think there should be little hesitation in resorting to amputation at the ankle joint under the circumstances in question.

During a period of study in Europe (probably in 1822 in Paris, where he attended Lisfranc's course of surgical operations on human cadavers and Dupuytren's lectures and clinical demonstrations), Syme learned the technique of Chopart's amputation for removal of part of a foot damaged or diseased. He introduced the procedure in Edinburgh in 1829, and the results he obtained convinced him of its merit.

Chopart's amputation (disarticulation at the mid-tarsal joint, long plantar flap) was seldom complicated by the hospital diseases that made amputations through the leg so dangerous, and it left the patient with a partial foot capable of weight-bearing and with a movable ankle joint above it. We now know that the success of Chopart's amputation was a demonstration of the principle that, in the presence of sepsis, disarticulation is a much safer procedure than is amputation through muscle masses and the open medullary cavities of long bones. Articular cartilage left on the end of a bone, or the subarticular cortical plate and the network of cancellous bone deep to it, serve as barriers to the spread of infection, whereas the intermuscular and interfascial planes of an amputation stump provide easy pathways for invasion by microorganisms. Syme could not know the true reason for the life-saving merit of Chopart's amputation because knowledge of bacteria and of wound infections was still in the future. His conviction of its value was founded on empirical experience.

Syme commented upon the merits of Chopart's amputation as follows:

> The operation of Chopart, which leaves only the astragalus and os calcis, is the most valuable of all partial amputations as it commands the largest portion of the foot requiring removal for disease or injury, and at the same time preserves a support for the patient not less useful than that which is afforded by the whole of the tarsus. Its introduction was long opposed on the ground that the extensor muscles of the ankle, acting through the tendo achillis, when no longer antagonized, would draw up the heel and point the cicatrix to the ground. I performed this operation in 1829, so far as I know for the first time in Edinburgh (Great Britain?) and have frequently done so since with the most satisfactory result, no inconvenience having been experienced from the source just mentioned, as the cut ends of the tendons on the forepart of the joint speedily acquired new attachments enabling them to counteract the extensive power.

Syme's favourable impression of the merit of Chopart's disarticulation at the mid-tarsal joint led him to apply the same principle to the ankle joint when caries or compound injury involved the astragalus or calcaneus, problems for which Chopart's amputation was inadequate. He performed his first disarticulation at the ankle joint in 1842, thirteen years after his first Chopart amputation. The long delay in applying to the ankle joint the principle which was so successful at the mid-tarsal joint arose from the problem of how to make the long stump bear weight satisfactorily. Disarticulation at the ankle joint might prove as effective as Chopart's amputation in saving the patient's life, but the long stump would prove an intolerable nuisance unless the patient could walk upon it. In Chopart's amputation, walking upon the stump presented no problem since the whole of the posterior half of the sole of the foot remained intact, and upon this the patient walked almost as easily as upon a normal foot. Amputation at a higher level (a hand's breadth below the tibial tubercle) permitted weight-bearing by applying the flexed knee to the

padded cleft in the upper end of a crude prosthesis. This was "amputation at the site of election," a useful operation if the patient survived, but the mortality rate was 50 percent.

To make disarticulation at the ankle joint a functional success, some procedure was needed which would permit all the body weight to be borne upon the end of the stump in a manner similar to Chopart's stump. Other surgeons had attempted to solve this problem without success. Syme's solution was to detach from the underlying tarsal bones the whole thickness of the posterior half of the sole of the foot, disarticulate the astragalus from the mortise of the ankle joint, remove the malleoli, and then reapply the heel flap to the lower ends of the tibia and fibula. This proved to be the technique necessary for a satisfactory end-bearing stump at the level of the ankle joint for it provided a thick and bulky covering for the end of the stump composed of tissue adapted to weight-bearing.

Syme's account of the development of his new operation is interesting *(32,36)*:

> The idea of amputating at the ankle joint is not new, the operation having been performed on the Continent by different surgeons before I thought of it; and it would probably ere now have become generally adopted but for the doubt that was entertained as to the ends of the bones being sufficiently covered to afford the patient a comfortable and useful support for the limb. For my own part when I read of dissecting flaps of skin from the instep, or sides of the foot, I felt so much distrust in the protection that could thus be effected against the injurious effects of pressure on a part so exposed to it, that I had no desire to try the experiment. But it occurred to me, that by performing the operation in a different way all such objections might be obviated. This was to save a flap from the sole of the foot and the thick integuments of the heel, by making a transverse incision, and dissecting these parts from the os calcis, so that the dense structures provided by nature for supporting the weight of the body, might still be employed for the same purpose. Two trials of this operation having proved satisfactory, I communicated them to the profession, and am glad to find that not only my colleagues in the hospital here, but also practitioners in other planes have already acted upon this recommendation. The additional experience of my own practice now enables me to suggest some improvements in the mode of procedure—point out an error to be avoided [this was cutting the posterior tibial artery before division into the median and lateral plantar branches]—and verify the expectation formerly expressed as to amputation of the leg being hardly ever required.

Since Syme does not say why it took him so long to evolve this successful technique, we can only speculate upon the reasons. It may be that the principle of raising a skin flap and then replacing it in a new position was sufficiently radical to make him hesitate. This is a possibility for it was known that amputations with flaps were more prone to postoperative troubles than circular amputations. Or it may be that he was so immersed in the many other new surgical procedures he introduced that time elapsed before he gave thought to disarticulation at the ankle joint. Or it may be that it required thirteen years of experience with Chopart's amputation to convince him that disarticulation was so much more safe than amputation that he would be justified in applying the principle to the ankle joint. Probably this last supposition is important. In the era of "hospital diseases" it was of immense value to know that disarticulations could with certainty be relied upon to heal without the complications which after amputations endangered life and marred the healing of the stump.

Syme's first patient *(30,36,37)* was a 16-year-old boy who suffered from caries of the tarsal bones, almost certainly tuberculosis. Syme described the problem, the operation, and the result in his first published paper on the subject *(30)*:

> John Wood, aged 16, was admitted to the Royal Infirmary on the 8th of September, 1842, suffering from disease of the foot which had suppurated and ulcerated in consequence of a twist he had given to it in walking about twelve months before. The instep was swollen and there were two openings discharging pus. A probe entered the sinuses freely into the substance of the tarsal bones, more particularly the astragalus and os calcis. ... As the disease had extended beyond the limits of Chopart's amputation it would have been necessary in accordance with ordinary practice to remove the leg below the knee, but as the ankle joint seemed sound I resolved to perform a disarticulation there. With this in view, I cut across the instep in a curved direction with the convexity towards the toes, and then across the sole of the foot so that the incisions were nearly opposite one another. The flaps thus formed were next separated from their subjacent connexions which was easily effected except at the heel where the firmness of texture caused a little difficulty. The disarticulation being readily completed, the malleolar projections were removed by means of cutting pliers.

Although a small slough separated from the

edge of the lower flap, in which a counter-opening had to be made for the drainage of matter, the patient recovered with little reaction and left the hospital in three months. Five months after the operation:

> . . . the wounds were soundly healed, and any degree of pressure can be born by the stump which has a round form, well suited for the adaptation of a boot or artificial foot, and is strongly protected from external injury by its thick integument.

The success of his first case led Syme to the following conclusion:

> It thus appears that compound dislocation of the astragalus and caries of this bone and the surrounding articular surfaces are the principal cases for amputation of the leg. This amputation can usually be superseded by amputation at the ankle joint. . . . The advantages promised by amputation at the ankle joint instead of operation near the knee are: 1st, That the risk to life will be smaller: 2nd, That a more comfortable stump will be afforded and 3rd, That the limb will be more seemly and useful for progressive motion. ... On these grounds I think amputation at the ankle joint may be advantageously introduced into the practice of surgery. I regret having cut off many limbs that might have been saved by it, and shall be glad if what has been said in its favour encourages others to its performance.

Between 1843 and 1846 Syme wrote four more papers on amputation at the ankle joint *(31,32,33,35),* and he reprinted them with a summary in *Contributions to the Pathology and Practice of Surgery (36).* Therein he states:

> I have operated in more nearly two than one dozen of cases with perfect success.

Years later (1857) he wrote again to attest to the satisfactory results obtained by his amputation at the ankle joint *(37).* He had been aroused by a review in *Lancet (13)* of the then new (4th) edition of Fergusson's *System of Practical Surgery,* in which appeared the following sentence: "Mr. Fergusson states, in relation to removal of the foot at the ankle joint in the manner recommended by Mr. Syme; that he had formed from experience a most unfavourable impression against it." Syme wrote to the editor of *Lancet* to refute Fergusson's statement. He said:

> Sir,
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> Fifteen years ago I proposed a mode of affording relief from diseases that had been held to require amputation of the leg, by removal of the foot at the ankle-joint. This proposal was favourably received, and has long since been adopted by intelligent surgeons at home and abroad as the established procedure in cases proper for its performance. It is easily executed, and proves in the highest degree satisfactory, if done in accordance with certain principles which have been carefully explained, but is difficult and disastrous if performed incorrectly.

He then included letters from three patients upon whom he had performed his amputation at the ankle joint, respectively 10, 14, and 15 years earlier. One of them was his first case. All were well—with useful, painless stumps on which they could walk without difficulty and without a prosthesis if necessary.

Before Syme died in 1870, the problem of hospital diseases was in the process of solution as the result of the clinical studies of his son-in-law, Joseph Lister. Today, more than a century since Syme first wrote on amputation at the ankle joint, we have accumulated an immense fund of knowledge on the problem of infection in surgery, and we have at our command effective measures for its control. The technique of aseptic surgery and the rigid standards of cleanliness and hygiene in operating rooms and hospitals have to a large degree enabled us to eliminate infection from our surgical procedures. When infection does occur, we can now do more to control it with antiseptic and bacteriostatic and antibiotic agents than has ever before been possible. Today, therefore, the merit of Syme's amputation lies not chiefly in the circumstance that "the risk to life will be smaller." On the other hand, it still remains the most useful of all amputations of the lower extremity "because a more comfortable stump is provided, and the limb is more seemly and useful for support and progressive motion."

Of historical interest in demonstrating Syme's conviction of the merit of end-bearing stumps in the lower extremity is the record of his attempt to devise, at the level of the knee, an end-bearing stump embodying the principles which had proved so successful at the ankle. Two years after his first account on amputation at the ankle joint he reported the results of his attempt on two patients to remove the lower extremity at the knee and to close the wound with a skin flap so that weight could be borne on the end of the stump

(34). Both patients seem to have been suffering from tuberculosis of the knee joint. In both, the femur was transected through the condyles just above the carious articular surface, and the end of the stump was covered with a long posterior flap of skin derived from the calf. Both wounds healed without complication, though they took a long time to do so.

It seems evident from Syme's presentation of these two cases that he was concerned chiefly with devising an operation safer than amputation through the shaft of the femur and that he believed that transection through cancellous bone just above the articular surface would involve less risk from hospital diseases than would amputation at a higher level. Since he did not cover the end of the stump with skin accustomed to weight-bearing, he evidently believed that the achievement of a healed stump without sepsis and without serious risk to the life of the patient was the prime objective and that good function and even end-bearing would follow good healing.

Twenty-one years later *(38)* he wrote again about transcondylar amputation of the femur. His interest had been renewed by Carden's report *(8)* of a method of amputating through the knee or through any part of the lower end of the femur using to cover the end of the bone a single, long, anterior flap composed of skin and subcutaneous tissue only. The muscles were divided at the level of transection of the bone and thus were excluded from the flap as was also the patella. Carden's purpose was to avoid the thin, sensitive, adherent cicatrix ("retreating muscles and obtrusive bone"), which so frequently resulted when equal flaps were used, and to cover the end of the femur with a broad cap of skin and subcutaneous tissue accustomed to bearing the weight of the body in kneeling (Fig. 2). Syme warmly commended Carden's amputation, which he said could be performed with little risk to the patient and had the additional advantage *(38)* that:

> . . . the stump proved eminently serviceable since the skin over the bone, instead of becoming thinner, acquired additional thickness so that patients could

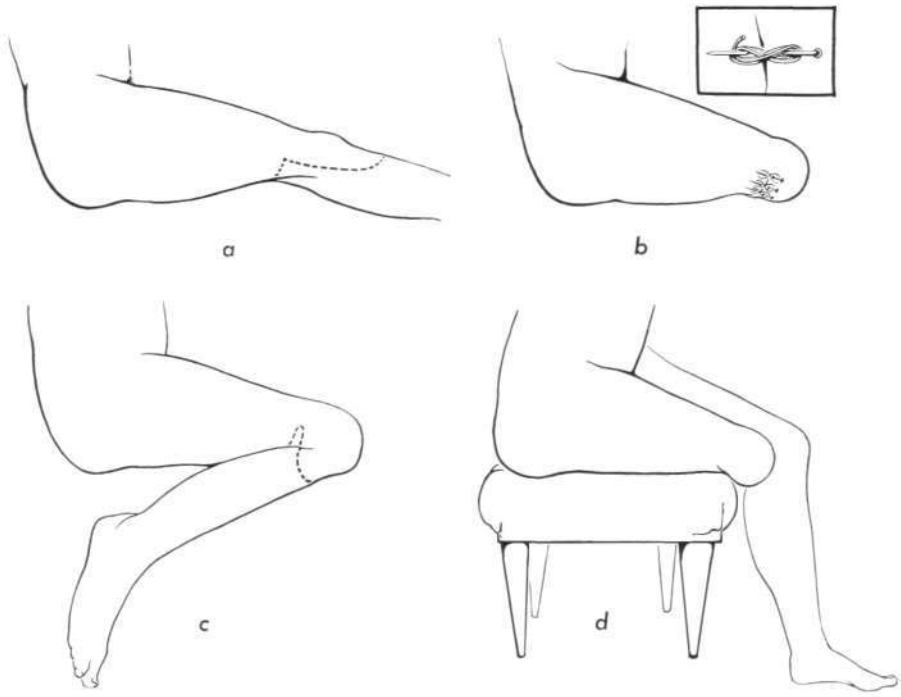


Fig. 2. Carden's operation by single flap, *a,* The line of the skin incision; *b,* closure of the wound; *c,* ankylosis of the knee in extreme flexion deformity following fractured patella; *d,* the end-bearing stump obtained by Carden's operation on the limb illustrated in *c.* From Carden *(8).*

rest upon it just as they do after amputation at the ankle.

In the same publication, Syme acknowledged that his earlier attempt to perfect the technique of transcondylar amputation had failed and that the method had fallen into disuse because the skin flap derived from the calf of the leg "proved very inconvenient." Syme, therefore, nearly achieved success in devising an end-bearing stump at the transcondylar level. He failed because his attention was focused upon the avoidance of sepsis and because he did not appreciate the importance of covering the end of the stump with skin naturally adapted to weight-bearing—a strange circumstance since he seems to have been well aware of the value of "the thick integuments of the heel" in the ankle-joint cases.

DEVELOPMENT OF SYME'S AMPUTATION

Shortly after Syme's first publication on amputation at the ankle joint *(30),* the operation began to be adopted in England and Scotland, generally with satisfactory results. In subsequent publications Syme stressed details of technique he had found essential for success *(i.e.,* avoidance of damage to the posterior tibial artery, separation of the heel flap by dissection close to the calcaneus, drainage of the dead space, etc.). By 1846 he had perfected the technique of the operation, and from then on he accumulated experience in the application of the procedure to various problems. But he wrote nothing more on the operation except the letter to the editor of *Lancet* in 1857 *(37).*

BAUDENS' TIBIOTARSAL AMPUTATION

On the Continent, and especially in France, there was less ready acceptance of Syme's amputation, partly because a somewhat similar amputation *(2)* had been reported by Baudens (Fig. 3) in 1842, a year before Syme's first publication. Described as a "tibiotarsal amputation," it involved a procedure in which the foot was removed by disarticulation at the ankle joint accompanied by removal of the malleoli and the posterior half of the inferior articular surface of the tibia by a single saw cut. The end of the stump was covered with a flap from the dorsum of the foot which included in its thickness all the structures from the skin to the tarsal bones and intertarsal ligaments (skin, subcutaneous tissue, tendons, nerves, and blood vessels). Baudens' concern was to secure good healing by a flap which would drape itself over the end of the stump as the patient lay supine in bed and when healed would provide a long stump on the end of which the patient could walk (Figs. 4, 5, and 6). When reports of Syme's operation reached France, there was renewed appraisal of Baudens' cases, and the columns of *Les Annates de Therapeutique* for 1845-1847 contain several references to the problem. The following editorial comment *(2)* is typical:

> Our readers already know the tibiotarsal amputation of the foot which Doctor Baudens performed several years ago on a young soldier at the Gros-Caillou Hospital. We followed the patient in this hospital and then at the Val-de-Grace to which he had been transferred and we were happy one year later to see him walk well with the aid of an ordinary dancing shoe supported by two small metallic splints. This soldier took long walks without fatigue, went upstairs and went down slowly, danced and jumped with agility. His peg leg made him an excellent support and all without even a limp. We were extremely satisfied with this result in spite of the fact that one or two other patients who had had this operation performed upon them by Doctor Baudens had succumbed from gangrene of the flaps. Doctor Baudens' patient was admitted subsequently to l'Hotel des Invalides. Soon we found him again admitted to the Infirmary of the Hotel and for several months he has continued there. His stump has become excessively painful. The cicatrix has re-opened and has ulcerated at several points. Doctor Hutin, the surgeon-in-chief, has been obliged to open two small new abscesses which had formed in the tissue of the scar and it is probable that the underlying bones are affected. The patient complains of acute suffering and he demands with earnest insistence an amputation near the knee. M. Hutin will probably be obliged to come to that. This fact raises questions which demand an explanation. Let us first remark that the indifference with which our surgeons, civil and military, have received the remarkable memoir of M. Baudens is not a proof that the operation is without value for it has been practised in Edinburgh by M. Syme half a score of times with complete success. (We say indifference for the reason that no French surgeon to this day has himself performed or even recommended M. Baudens' valuable operation.) It is true, however, that M. Syme had generally operated only upon children and that he had pub-

lished only the immediate results of the operation. Now the question is what are the remote effects (of the operation) since the scar in M. Baudens' patient was not inflamed or ulcerated and did not re-open for more than a year after the operation. It is all the more important, therefore, to know the actual state of M. Syme's patients for this knowledge could decide whether in the patient at Les Invalides, the evil in the scar derives from morbid constitutional conditions as we have presumed or to inherent conditions in the form of the flaps or in the stump. We should recall that in M. Baudens' operation the top of the ankle is sawed off after the disarticulation, while M. Syme *preserved the ankle intact.* Let us say finally that until new facts come to enlighten the above questions and in spite of the very great aversion the civil and military surgeons show to adopting the tibiotarsal amputation, we persist in believing it beneficial in most cases which we have from time to time indicated. Amputation at the wrist is satisfactory; why then hesitate to operate at the same level in the inferior member? We know the reasons of those who oppose. Time and new facts will be the best judges.

We should not terminate this article without stating that there prevails in military practice a sort of aversion for all those operations which one could perhaps call *de luxe* such as partial amputation of the foot, supramalleolar amputation, etc. For several reasons orders have been to adopt the same treatment for all cases. It is otherwise in civil hospitals. We have already discussed the diverse questions connected with these declarations.

Fig. 3. J. B. L. Baudens, the French military surgeon who published in 1842 the account of his tibiotarsal disarticulation. *Courtesy National Library of Medicine, Washington, D. C.*

This editorial was reproduced in the Monthly Journal of Medical Science, where it came to Syme's attention *(36).* Certain inaccuracies demanded correction, and there was the implication that perhaps Syme's results were not as good as they were said to be or that, if they were, the reason should be found so that Baudens' operation could be modified and made acceptable on its merits.

Syme therefore wrote to the editor of the *Monthly Journal of Medical Science (35)* to clarify the points in confusion. The gist of his reply was as follows:

1. He had operated upon a considerable number of patients (more nearly two than one dozen of cases) with complete success.

2. Most of his patients were adults (not children as stated by the editor of *Les Annates de Therapeutique).*

3. In one case only did he leave the malleoli intact and that was the case of an infant five months of age with an erectile tumour of the foot.

4. His results were satisfactory, in evidence of which he quoted from letters received from his first three patients, each of whom stated that the stump was satisfactory and was scarcely any handicap.

5. His mode of performing the operation was to obtain a heel flap of sufficient length by cutting from the tip of one malleolus to the tip of the other. By this the risk of sloughing was lessened if not entirely prevented.

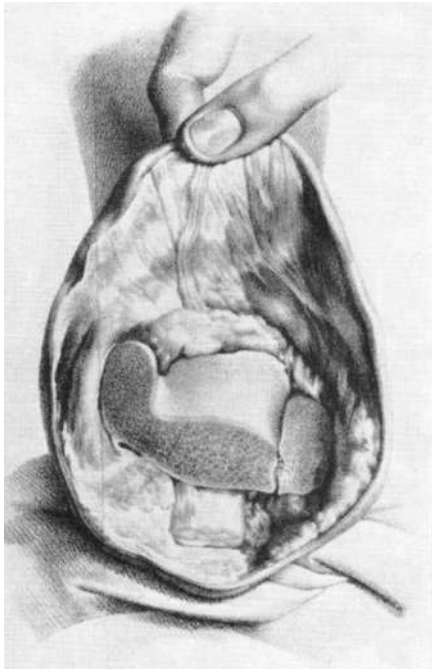


Fig. 4. Baudens' tibiotarsal amputation. Appearance of the stump after removal of the foot. The malleoli have been removed with the posterior margin of the articular surface of the tibia. The long dorsal flap is held up. Left to itself, it fell naturally over the cut ends of the bones and required the minimum amount of fixation. From Baudens *(2)*.

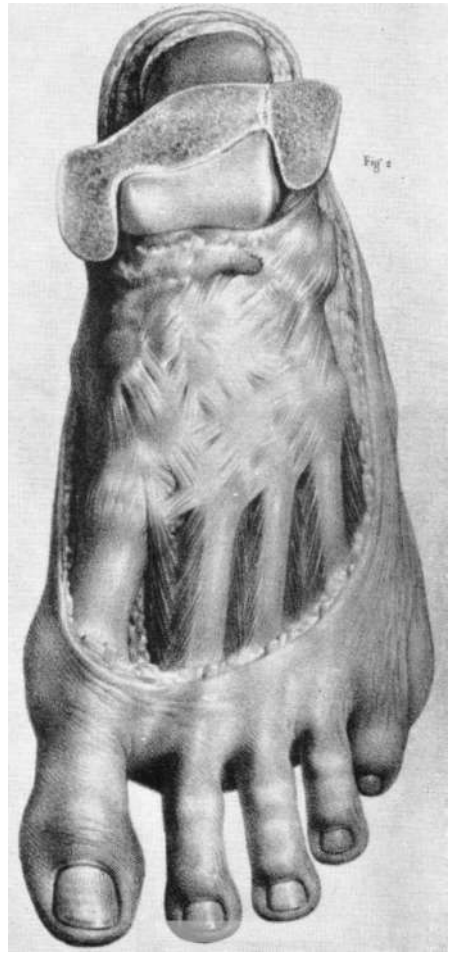


Fig. 5. Baudens' tibiotarsal amputation. Appearance of the foot after its amputation. The denuded area on the dorsum of the foot indicates the extent of the flap and shows that it included in its thickness all the tissues from the skin to the tarsal bones and intertarsal ligaments. From Baudens *(2)*.

The fact is that there was an essential difference between Baudens' tibiotarsal amputation and Syme's amputation at the ankle joint. Both surgeons were striving to devise, for treatment of disease of the foot beyond the scope of Chopart's amputation, an operation which would replace amputation below the knee. They desired to diminish the risks to the patient's life and to leave him with a long, well-covered, unscarred stump capable of total end-bearing. Both surgeons disarticulated the foot at the ankle and removed the malleoli, with or without a thin flake from the lower end of the tibia. The essential difference lay in the nature of the flap used to cover the end of the stump. Baudens used a long flap from the dorsum of the foot because it would drape itself naturally over the end of the stump while the patient lay supine in bed. It required the minimum of fixation and permitted free drainage in the immediate postoperative period. Syme used a plantar flap in order that he might cover the end of the stump with the thick integument of the heel.

Syme's amputation at the ankle joint proved superior to Baudens' tibiotarsal amputation even in the days before antisepsis. Today, with infection eliminated as an operative risk, Syme's operation has even more to recommend it as the best operation of the lower extremity.

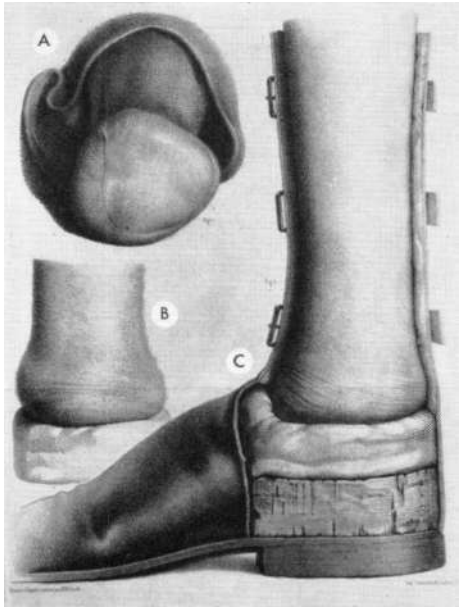


Fig. 6. Baudens' tibiotarsal amputation, *a,* End of the stump when completely healed; *b,* appearance of the stump when bearing weight; *c,* simple prosthesis fitted into a boot with a high, laced top. From Baudens

In addition to Baudens' tibiotarsal amputation and Syme's amputation at the ankle joint, several other amputations of the foot in the region of the ankle were devised in the latter half of the nineteenth century with the purpose of avoiding the grave complications of amputation through the leg and to provide an end-bearing stump. Though none of these proved to have the value of Syme's amputation, they are of historic interest.

ROUX'S AMPUTATION

Roux's amputation (1845) was a supramalleolar amputation *(19,27)* with a medial flap to cover the ends of the tibia and fibula (Fig. 7). The tibia and fibula were divided transversely above the articular cartilage, and the medial flap included all the skin on the medial side of the foot as far forward as the talonavicular joint and as far inferior as the inner margin of the sole of the foot. The advantages claimed were that the flap had an assured blood supply from the posterior tibial artery and that a weight-bearing stump could be salvaged from a foot with a heel flap damaged too extensively to permit a formal Syme's amputation. The disadvantage proved to be the inadequacy of the flap, which was too thin to withstand the stresses of weight-bearing.

It is interesting to record that Roux came to recognize the superiority of Syme's amputation. In 1846, after performing his first disarticulation of the ankle joint by Syme's method, he said *(16):*

> It appears to me that by this operation art modifies without changing the language of nature; in fact, the malleoli being removed, the lower extremity of the leg affords a base of support which transversely exceeds that of the os calcis.

GUYON'S AMPUTATION

Guyon's elliptical supramalleolar amputation with posterior flap (1868) was performed *(15)* by a single elliptical incision which encircled the heel and the front of the ankle joint (Fig. 8). Only a finger's breadth of skin from the plantar surface of the foot in front of the heel was retained. A flake of the os

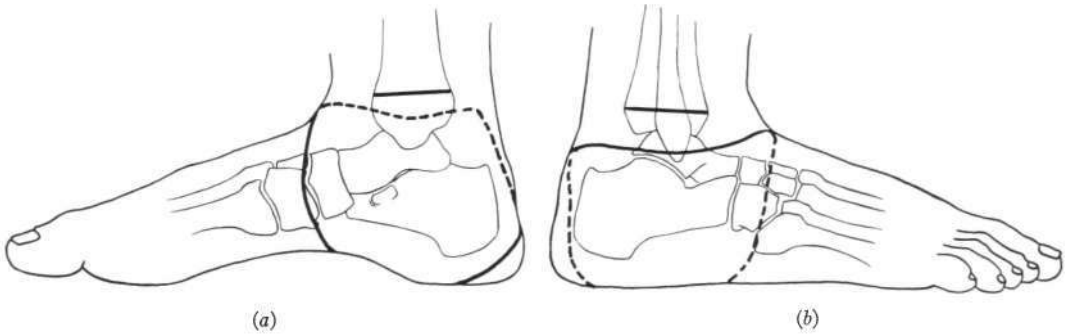
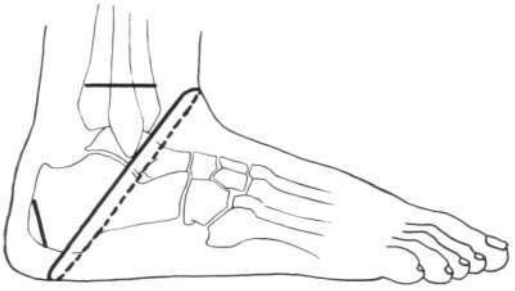


Fig. 7. Roux's supramalleolar amputation with medial flap, *a,* Medial view; *b,* lateral view. Redrawn from Jacobson *(19).*



Fig, 8. Guyon's elliptical supramalleolar amputation with posterior flap. Redrawn from Farabeuf *(12).*

calcis was removed at the insertion of the tendo achillis and retained with the heel flap, and the tibia and fibula were transected above the articular surface of the tibia. The heel flap, with its flake from the posterior end of the os calcis, was applied to the cut surfaces of the tibia and fibula, and the skin margins were sutured. The weakness of Guyon's amputation lay in the inadequate heel flap, which did not stand up under the stress of weight-bearing, and the small tapered end of the stump, which provided too small an area of support.

Fig. 9. Nicolai Ivanovitch Pirogoff (1810-1881), who devised his amputation at the ankle to overcome certain features of Syme's amputation that he regarded as detrimental. From *Pirogoff: Collected Works,* Vol. 1, State Publications Medical Literature, Moscow-Leningrad, U.S.S.R., 1959. Print obtained through the courtesy of Dr. W. G. Bigelow and the Russian Ambassador to Canada, His Excellency A. A. Aroutunian.

PIROGOFF'S AMPUTATION

In 1854, Pirogoff (Fig. 9), the greatest Russian surgeon of his day, published the account of his new operation at the ankle joint *(26),* which he intended as an improvement upon Syme's amputation. In 1847, at the Clinic of Professor Chelius at Heidelberg, Pirogoff had seen two patients upon whom Syme's amputation had been performed, and he was impressed with the results. In 1848 and 1849 he performed Syme's amputation on four patients, all of whom died (one of pulmonary tuberculosis, one of scurvy, and two of sepsis, one of whom had gangrene of the heel flap). In a fifth case, an attempt to perform Syme's amputation failed because of gross damage to the heel flap incurred in separating it from the calcaneus. Nevertheless, Pirogoff, in his attempt to deal with compound injuries and caries of the astragalus and calcaneus by some method better than amputation below the knee, continued to use Syme's amputation at the ankle joint as well as Baudens' tibiotarsal amputation and Roux's supramalleolar amputation with a medial flap. From his experience he came to the following conclusions:

1. The most difficult part of Syme's amputation is the separation of the heel bone from the skin. Only with

great care can the tightly adherent skin be separated without injuring the flap or making it too thin.

2. In Syme's operation, the skin over the tendo achillis forms the base of the flap and is much thinner than the apex of the flap. If care is not taken, it may be cut too thin and the flap may become gangrenous.

3. A considerable depression remains in the heel flap of Syme's amputation after the os calcis is shelled out. It may form a pocket for the collection of pus.

4. In the method of Baudens, the skin over the lower surface of the os calcis is removed. In this operation the creation of a foundation for the stump is not accomplished as it is in Syme's method, where the thick skin of the sole of the heel forms a sturdy covering.

5. In Roux's method, the formation of the posteromedial flap is certainly easier than in Syme's method. The base is wider, and necrosis occurs less often because the posterior tibial artery is cut below its division. However, the base of the flap is thinner than the summit. The depression in the flap is just as deep as in Syme's method, and, finally, the Achilles tendon is completely cut at its attachment to the os calcis as in the two previous cases.

In order to avoid these inconveniences, Pirogoff devised a new procedure (Figs. 10, 11, 12, and 13). The skin incisions resembled those of Syme. The skin, soft tissues, and tendons were divided down to the bone, and

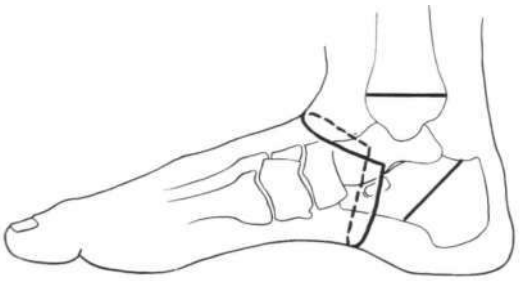


Fig. 10. Pirogoffs amputation. Redrawn from Pirogoff *(26)* and Elmslie *(11).*

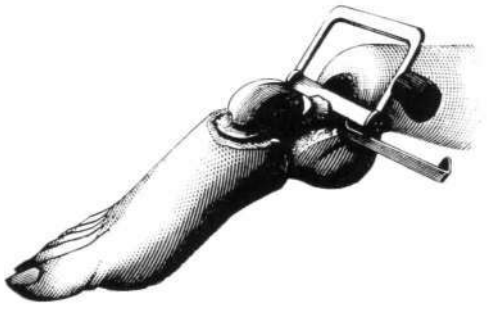


Fig. 11. PirogofFs amputation. Dividing the calcaneus. From Farabeuf *(12).*

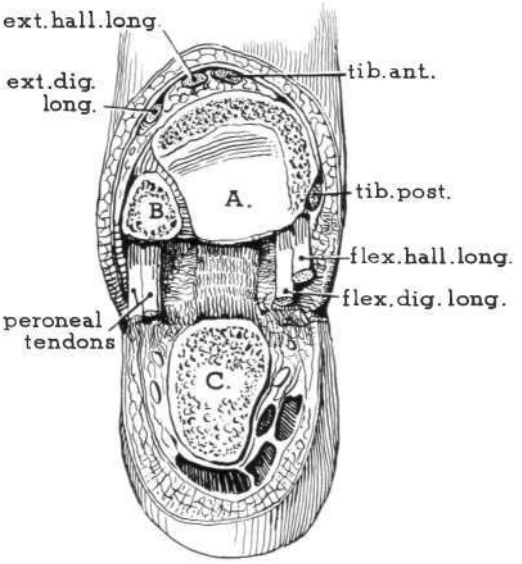


Fig. 12. Pirogoffs amputation. Appearance of the stump after removal of the foot by disarticulation at the ankle. *A,* Tibia; B, fibula, *C,* os calcis "sawn behind *lig. sustentaculae"* Redrawn from Pirogoff *(26).*

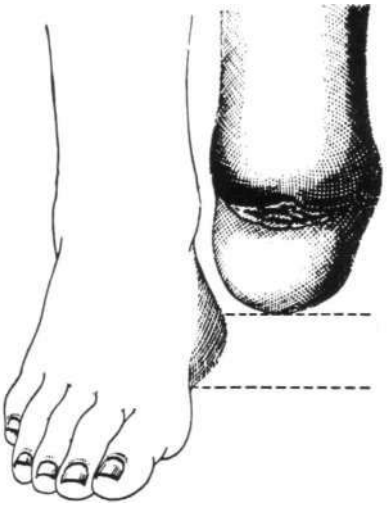


Fig. 13. PirogofFs amputation. Appearance of the healed stump. Redrawn from Pirogoff *(26).*

the ankle joint was entered from in front by dividing the capsule anteriorly. The lateral ligaments were detached from the malleoli and the astragalus displaced downwards. The capsule was then opened posteriorly and the superior surface of the calcaneus exposed. A saw placed through the two vertical limbs of

the plantar incision and across the superior surface of the calcaneus behind the body of the astragalus and in front of the tendo achillis divided the calcaneus obliquely from above downwards at the junction of the middle with the posterior third of that bone. The posterior third of the calcaneus and the tendo achillis retained their normal attachments and formed an integral part of the heel flap. The malleoli were divided at their base and removed level with the articular surface of the lower end of the tibia. The inferior articular surface of the tibia was not removed unless it was diseased. When the vessels had been ligated, the heel flap was turned up and secured to the margin of the anterior flap by two or three sutures.

The operation was ingenious and had certain merits. If the wound healed satisfactorily and the calcaneal fragment fused to the tibia, an end-bearing stump resulted, longer than a Syme's stump, so that no prosthesis was necessary to compensate for the shortening. The patient walked without much "dipping" (limp). Also the heel flap was firmly fixed in place by fusion of the calcaneal fragment to the tibia. But there were risks which could mar the success of the operation. If the calcaneal fragment failed to unite to the tibia, an unstable and painful stump end resulted. If the wound became infected, chronic osteomyelitis with persistently discharging sinuses was prone to establish itself in the calcaneal fragment or in the lower end of the tibia. Weight was borne ultimately upon the skin over the back of the heel, an area not as well suited to weight-bearing as is the plantar surface of the foot. For success, the calcaneus had to be free of disease and the heel flap not seriously damaged by trauma. In an age when the nature and management of infection was unknown, it was an operation technically difficult and uncertain in its results. Pirogoff's first three cases were all complicated by serious sepsis, and many months elapsed before they could walk on their stumps. Even then they still had discharging sinuses. Syme's operation was easier to perform and more certain of a good result, and these advantages still prevail.

SUBASTRAGALAR AMPUTATION

Subastragalar disarticulation was first mentioned by Velpeau in a single small paragraph in his *New Elements of Operative Surgery (43).* He stated that it had been proposed to him by des Lingerolles, who seems not to have been a surgeon. At the time Velpeau had not performed the operation. He merely mentioned it as a promising procedure in selected cases of disease or injury of the foot. Farabeuf *(12)* perfected the operative technique and described it with excellent engravings in his *Precis de Manuel Operatoire (12).* He also discussed its merits and limitations. There is also a paper by Hutchinson *(18),* which contains a good description of the operation as well as a report upon the end result obtained in six cases. Five of his cases, operated upon by the technique described by Farabeuf, were gratifyingly successful, while the sixth, in which the flap was formed by a technique similar to that of Syme, was imperfect because the heel flap could not cover the head of the astragalus without undue tension.

Subastragalar amputation is of value in a limited number of cases, the best technique being that described by Farabeuf *(12).* A large internal and plantar flap extends to the outer margin of the heel and as far forward as the base of the fifth metatarsal (Fig. 14). The subastragalar and astragaloscaphoid joints are opened from the lateral side, and the heel is inverted until the medial side of the os calcis can be reached. The os calcis is then freed from the heel flap beginning at the medial surface and is removed with the foot. Care must be

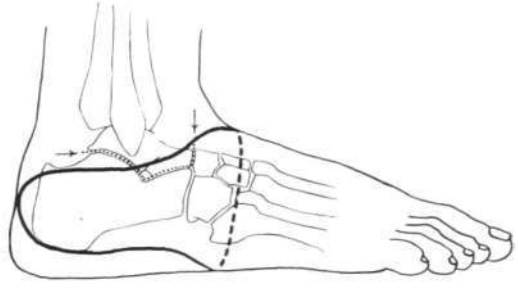


Fig. 14. Subastragalar amputation of de Lingerolles and Velpeau giving large plantar flap. Redrawn from Farabeuf *(12).* Dotted line is the plane of subastragalar disarticulation.

taken to avoid injury to the posterior tibial artery. The advantages over Syme's amputation, as stated by Hutchinson, are:

1. The stump is some 2 in. longer than a Syme's stump.
2. It gives a broader base of support.
3. The elasticity due to ankle movement is of marked advantage in walking.
4. The pad at the end of the stump is much thicker.
5. The arterial supply is better and runs less risk during the operation.
6. The artificial foot can be better fitted to the stump.

Hutchinson states that between 1891 and 1900 Syme's amputation was performed under antiseptic surgery on 27 patients at the London Hospital. The outcome: complete failure, 3 (one died); suppuration and sloughing of flap, 12; good result, 12. Several factors other than imperfection in technique *(e.g.,* difficulty in sterilizing the skin of the heel flap, delay in operating because of patient's "obstinacy," operation in unpromising cases) contributed to the poor results. Even with the advantages of anaesthesia and antisepsis, the results at the London Hospital were inferior to those of Syme. In his meagre accounts of long-term results, Syme makes no mention of a fatality, and the functional results were good. For best results from Syme's amputation, the cases must be selected carefully, and the operation has to be timed wisely and performed skillfully.

In Hutchinson's paper also is an informative note, quoted from Clinton Dent *(10),* on the amputations in the South African War. The following is a summary:

Syme's amputation was performed in a small number of cases, but the resulting stumps were not entirely satisfactory. Damage of the foot from trauma is perhaps not as good an indication for Syme's amputation as is tuberculosis, because of damage to the skin. Sloughing of the flap sometimes occurred. Syme's amputation depends more than any other upon very careful attention to the details of the technique.... In Syme's amputation it is really impossible to depart from the lines laid down by Syme in the fashioning of the flaps. [It will be remembered that Syme emphasized this in almost the same words in his letter to the editor of *Lancet* (37) already quoted.] There may be merit in the subastragalar amputation. English surgeons are too limited in their methods of operating upon the foot and have a good deal to learn from their French colleagues.

The variety of ankle amputations introduced in the latter half of the nineteenth century is an indication of a common purpose on the part of the surgeons of that era. They were attempting to replace the dangerous operation through the upper end of the tibia with the safer disarticulation at the ankle and at the same time to provide for the end of the stump a covering which would withstand the period of postoperative sepsis without undue damage and which could ultimately permit weight to be borne upon the end of the stump. When we recall that, in its early years, Syme's amputation was performed without the benefit of anaesthesia, it is not surprising that sometimes it was executed imperfectly. Time has proved that success in Syme's amputation is dependent upon precise adherence to a particular technique. Even in today's era of advanced surgery, it still is necessary, if we are to avoid imperfect results, to use a technique which differs in no essential detail from that used by Syme.

In Syme's day, the chief difficulty that hampered the general acceptance of his procedure was the frequent occurrence of necrosis of the heel flap, and we can appreciate from Hutchinson's account that it was still a problem even in 1900 with benefit of antiseptic surgery. According to Dent also *(10),* necrosis of the heel flap was a complication of Syme's amputation performed on soldiers in the South African War. The chief cause of necrosis of the heel flap was injury to the posterior tibial artery. Syme himself learned, in the hard school of experience, the necessity for preserving this vessel *(32,36).* His account is as follows:

In describing the operation, I have said that care must be taken to avoid cutting the posterior tibial artery before it divides into the plantar branches and I may now explain more particularly the ground on which this advice is founded.

Elizabeth Wilson, aged seven, was admitted on the 19th of February on account of disease in her left ankle. . . . The foot was much enlarged, stiff and shapeless; and two sinuses allowed a probe to pass into carious bone.

On the 21st I proceeded to amputate at the ankle joint, but finding that anchylosis had taken place between the articular surfaces, I exposed the extremities of the tibia and fibula, and sawed them through without previously removing the foot as usual. In tying the vessels, it appeared that the posterior tibial artery had been divided before its division into the plantar branches, so that one ligature sufficed in place of two.

The stump looked remarkably well and the result of the operation was expected to prove very favourable. It was, therefore, with much surprise, and no small disappointment, that in the course of a few days I saw the flap had sloughed through fully half its extent. Recovery was consequently delayed much beyond the ordinary period. . . .

I attributed the sloughing in this case to the undue pressure of the bandage; and having occasion soon afterwards to perform the operation on a patient in Minto House, intentionally divided the posterior tibial before its division, in order to obtain the same facility in tying the vessel as on the last occasion. To my surprise and concern, the flap again sloughed to the same extent as in the case just related, and as great attention had been paid to the dressing of the stump, I could not refer this effect to the cause formerly supposed. But as on both occasions the artery had been cut before its division, while in all other cases it had been left entire, and as the flap, being deprived of nourishment from most of its ordinary sources, must be supplied with blood only through the successive anastomoses of small vessels, I concluded that this deviation from usual practice had led to the mischief in question, and I resolved to avoid it for the future.

A further cause of poor result from Syme's amputation was damage inflicted on the skin over the heel while the flap was being separated from the calcaneus or while the tendo achillis was being detached from its insertion. Unless the plane of dissection hugged the calcaneus, and unless the dissection was performed with precision and delicacy, the skin was apt to be buttonholed. It was this problem especially that led Pirogoff to introduce his operation and Guyon to devise his elliptical supramalleolar amputation at the ankle joint. Syme's amputation, then and now, is an operation which must conform rigidly to an exact technique. If it is not performed properly when first attempted, many of its advantages will be lost irretrievably. It is interesting that the technique necessary for success is almost exactly that which Syme himself ultimately evolved. As we shall see later in the section on technique, the only addition of proven value is subperiosteal separation of the calcaneus from the heel flap. All other attempts at improvement have failed to achieve the success which follows the use of Syme's original technique.

The 1914-1918 war, with its innumerable casualties, renewed interest in amputations. One outcome was the publication of an English translation of the small volume, *Artificial Limbs* (4), written by the French surgeons Broca and Ducroquet. In discussing end-bearing stumps, this monograph makes no mention of Syme's amputation. It lists only supramalleolar amputation, disarticulation at the ankle joint, subastragaloid amputation, and osteoplastic amputation through the ankle joint. An editor's footnote with respect to supramalleolar amputation states, "In England, of course, this is always called a Syme's amputation." This statement is not strictly accurate since an important detail of Syme's amputation contributory to its success is the large area of support provided for the heel pad when the lower end of the tibia is left intact or virtually so. Syme's operation is not a supramalleolar amputation; it is a slightly modified disarticulation. French surgeons, particularly Farabeuf *(12),* were meticulous in distinguishing between disarticulations (in which group Syme's amputation was included) and amputations *(e.g.,* the supramalleolar operations of Roux and Guyon). It is true that Syme himself always referred to his operation as "amputation at the ankle joint," but in doing so he evidently used the term "amputation" in a general sense and not in the exact sense of Farabeuf. It is certain from Syme's description of his operations, and from the derivation of his operation from the disarticulation of Chopart, that Syme's operation was in fact disarticulation of the foot at the ankle joint with removal of the malleoli. Had Syme emphasized this as precisely as did Farabeuf, he might have prevented the innumerable supramalleolar Syme amputations which have been performed because of imperfect knowledge of Syme's technique or in the hope of obtaining an improved stump. These are the cases which have cast doubt on the value of Syme's operation, for the resulting stumps are functionally imperfect and may be complete failures.

E. C. Elmslie, who translated and edited the English edition of Broca and Ducroquet *(4),* formed a high opinion of Syme's amputation. In a footnote to the paragraph on low leg amputations allowing walking with end-bearing only, he says, after brief discussion of Pirogoff's amputation, subastragaloid amputation, and disarticulation at the ankle joint: "In fact, in this region there is Syme's amputa-

tion and a number of other far inferior amputations which should never be considered when a Syme amputation is possible." In 1924, in the section on amputations which he contributed to Carson's *Modern Operative Surgery (11),* Elmslie states with reference to Syme's amputation:

> When successful it yields an excellent stump which is capable of complete end bearing. It can be fitted with a simple and cheap stump boot known as an elephant boot. Upon such a boot a patient with a Syme's amputation can often walk ten or twelve miles. In fact, Syme's amputation is so satisfactory that it may be said that all other amputations of the foot at a lower level are obsolete except amputation of the toes or parts of the toes.

Despite the high regard in which he held Syme's amputation, Elmslie does not appear to have understood how essential for success is exact adherence to the precise details of Syme's technique. For reasons which probably were related to limbfitting problems, Elmslie felt it necessary to secure an improved Syme stump, and for that purpose he devised a modified Syme amputation which is described in his chapter on amputations in Carson's *Modern Operative Surgery (11).* It is the only procedure for Syme's amputation that is described and illustrated there. Syme's original technique is not mentioned. Elmslie does not state clearly why he felt it necessary to revise Syme's technique. However, he does state that the Syme stump was too long and the end too bulky. Almost certainly these represent criticisms by the limbfitters of Elmslie's day, who certainly had difficulties in designing, manufacturing, and fitting a satisfactory prosthesis for a Syme stump.

ELMSLIE'S MODIFIED SYME'S AMPUTATION

Elmslie's modified Syme's amputation *(11)* differed from the classical Syme's amputation in three essential particulars:

1. The heel flap was smaller.
2. The dissection was carried out from the dorsal to the plantar surface.
3. The tibia and fibula were transected at a level well above the ankle joint.

Apparently the purpose of these changes was twofold: to provide a small, neat, tapered end to the stump and thus avoid the bulge in the prosthesis necessary to accommodate a bulbous-ended stump; and to accommodate more easily the ankle-joint mechanism by high transection of the tibia and fibula.

Elmslie was not the first person to advocate high transection of the tibia and fibula to facilitate the introduction of an ankle joint mechanism in the artificial limb for a Syme amputation in the space between the end of the stump and the level of the ground. Henry Thompson (*39),* at a meeting of the Pathological Society of London on April 21, 1863, shared in the presentation of seven patients with Syme's amputation and two patients with Pirogoff's amputation. As reported in *Lancet,* Thompson's remarks were as follows:

> He [Thompson] would not enter upon the various points of comparison between Syme's amputation and that modification of it in which a portion of the os calcis is left in the flap, but would only refer to the different results which remained after the two operations *[i.e.,* Syme and Pirogoff] as regards the kind of artificial limb which is applicable afterwards. He thought it very important for the surgeon and the mechanician to act in concert in most amputations of the lower extremity and he therefore showed also two artificial limbs to illustrate the advantage in relation to this matter which the proceeding of Syme offered over that of Pirogoff. In the former the patient enjoyed the advantage of complete ankle joint movement of the limb; while in the other, the stump being so close to the ground, there was no room for it and the best substitute that could be applied was by iron hinges outside of the limb. . . . Mr. Thompson wished to point out the necessity of taking off a sufficient slice of bone, including the two malleoli instead of merely removing the lower portion of the latter, so as to avoid extreme width and a bulbous stump which was more difficult to fit with a well made artificial limb than a stump which tapered gradually from the calf downwards. . . . Mr. Thompson said that the objection to the bulbous form of the stump did not materially apply if the common circular shoe which is laced around the lower part of the leg was worn [elephant boot], but it did to the artificial leg.

In Elmslie's operation the skin incision was an ellipse (Fig. 15) which commenced on the plantar surface of the foot 3/4 in. in front of the point of the heel. Therefrom it extended obliquely upward and forward over either malleolus to a point on the anterior surface of the ankle 1 in. above the joint line. The ankle joint was entered, the foot depressed, and the medial and lateral ligaments of the joint divided from within the joint. The astragalus was then dislocated from the mortise

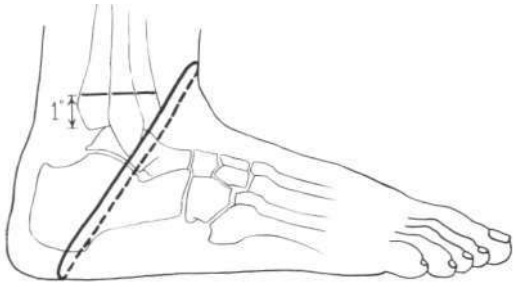


Fig. 15. Elmslie's modified Syme's amputation. Redrawn from Elmslie *(11).*

of the ankle joint by depressing the foot still farther. Doing so exposed the tendo achillis, which was then divided at its insertion. The calcaneus was then separated from the heel flap by dissection close to the bone from above downward. The tibia and fibula were transected3/4 in. to 1 in. above the highest level of the ankle joint, and the heel flap was then closed over the ends of the tibia and fibula.

Though Elmslie intended his modified Syme's amputation to be an improvement over Syme's original procedure, the result has not lived up to his expectations, and for three reasons: the small heel flap deprived the stump of an adequate covering of skin and subcutaneous tissue adapted to weight-bearing; the high transection of the tibia and fibula diminished the cross-sectional area of their cut surfaces and impaired their support for weight-bearing; the end of the stump was no longer bulbous but was tapered, a feature that permitted the artificial limb to slip up and down during walking. He succeeded in simplifying the limbfitters' problem, and he succeeded in making the stump neat and tidy, but in so doing he sacrificed the qualities of Syme's amputation essential for success—namely, a bulbous stump end to ensure that the grasp of the prosthesis would be secure and a wide area of bony support covered by a large, thick, heel pad adapted to weight-bearing.

Elmslie's modified Syme's amputation thus closely resembled Guyon's elliptical supramalleolar operation with posterior flap *(4,15).* It seems probable that in modifying Syme's operation Elmslie adopted Guyon's technique, for the only difference between Guyon's elliptical supramalleolar amputation and Elmslie's modified Syme's amputation was that in the former, unlike the latter, a flake from the posterior end of the calcaneus was removed along with the insertion of the tendo achillis and that later the flake was applied to the cut surface of the tibia when the heel flap was sutured into place. Elmslie's modified Syme's amputation was widely used in England (but not in Scotland) during the period following the 1914-1918 war, probably because of the confidence with which he advanced it as an improvement over Syme's technique and probably also because he made no mention of Syme's technique *(11).* It is likely that this adoption of his modified Syme amputation in England led to the dissatisfaction with Syme's amputation expressed by Langdale-Kelham and Perkins of Queen Mary's Hospital at Roehampton *(23).* They said ". . . this type of operation does not stand weight bearing on the average longer than eight years. . . . It is to be hoped that the modified Syme's amputation will soon be as obsolete as the original Syme's." The handbook of the British Ministry of Pensions, *Artificial Limbs and their Relation to Amputations (1),* also speaks with faint praise of Syme's amputation. In Scotland, in contrast to England, a rigid adherence to the precise details of Syme's original technique resulted in satisfactory end-bearing stumps. In Canada, for a similar reason, experience has also been satisfactory. The favorable results with Syme's amputation in Scotland and Canada as contrasted with the dissatisfaction with Syme's amputation in England is evidence that a wide area of bony support covered by a large, thick, heel pad is essential for a satisfactory Syme's stump. Syme's original operation provided these indispensable features, and consequently his stumps bore weight on the end satisfactorily and more or less indefinitely. Attempts to improve upon Syme's amputation *(e.g.,* the modifications of Roux and of Elmslie), chiefly in the matters of making the end of the stump neat and of providing the limbmaker with more space for the ankle joint of the prosthesis, proved unsatisfactory in the long run because the area of support was too small and because the covering over the end of the

stump would not stand up under long-continued end-bearing.

Syme was blessed by good fortune as well as good sense. His sound judgment brought him to the conclusion that disarticulation at the ankle joint and removal of the malleoli would constitute a safe and effective means for the removal of a damaged or carious foot. The idea of preserving the heel flap to cover the end of the stump and to provide end-bearing could have come only from profound insight. His courage, boldness, and skill enabled him to devise a simple technique by which these things could be accomplished. It was his good fortune that the operation he planned and the technique he devised have both proved to be of continuing value. He knew nothing of the minutiae which concern us today, and he ill understood the grave complications which often discounted the surgeon's efforts. But he was far-sighted enough and bold enough to embark upon a radically new approach to an old problem, to build upon his first successes, and to eliminate such defects as were present in his first efforts (*e.g.,* to preserve the integrity of the posterior tibial artery).

FUNDAMENTAL PRINCIPLES OF END-BEARING AMPUTATIONS OF THE LOWER EXTREMITY

The essential functions of the normal lower extremity are weight-bearing and locomotion, and amputation stumps in the lower extremity must be designed accordingly. The more perfectly they bear the body weight and transmit the forces of locomotion the more efficiently will they utilize prosthetic appliances. For purposes of weight-bearing, nothing is as satisfactory as a stump which can bear weight upon its end. Propulsion is best accomplished by a leg stump of the greatest possible residual length and with as many normally functioning nerves, muscles, and joints as can be preserved. Only two levels in the lower extremity can be adapted to provide end-bearing stumps—the lower end of the femur with a covering of prepatellar skin, and the expanded lower ends of the tibia and fibula covered by the heel pad.

To secure an end-bearing stump in lower-extremity amputations, certain requirements must be met:

1. In order to provide a broad area of support, the bone must be divided where its cross-sectional area is as great as possible.
2. The whole of the cut surface of the bone must be capable of bearing weight. This requirement can be achieved by a strong meshwork of cancellous bone across the whole area, or, in the case of the ankle joint, by retention of the subarticular cortical bone at the lower end of the tibia. The tubular cross-section of the shaft of the tibia at higher levels is unsuited to weight-bearing.
3. The skin and subcutaneous tissue covering the end of the stump must be appropriate for weight-bearing.
4. The weight-bearing skin must be properly centered upon the area of support and firmly attached to it.
5. The end of the stump must be bulbous, thus ensuring that the prosthesis will not slide off the stump or rotate upon it.

Syme's operation, properly performed, meets all these requirements. For conditions which require amputation in the vicinity of the ankle joint, it provides a stump superior to all others. But the initial operation provides the sole opportunity for securing a Syme stump satisfactory in all respects. Even minor deviations from detail are prone to result in a stump imperfect in one way or another, and such imperfections usually cannot be corrected by secondary operations. If the imperfection is not great, the stump may function reasonably well, for some time at any rate, but it may not stand up indefinitely, as has proved to be the case with Elmslie's modified Syme's amputation.

Because preservation of the unique structure of the heel pad is essential for attaining a perfect Syme stump, it is appropriate now to describe its specialized nature. In the human heel, as in other parts of the body adapted to weight-bearing (finger tips, thenar and hypothenar eminences, ischial tuberosities, and prepatellar pads), the ability to withstand the stresses imposed by the weight of the body and by body movements derives in part from the thickness of the skin and in part from a special elastic adipose tissue beneath the skin. Of the two, the latter is the more important, for without the buffering action of this elastic adipose tissue not even a thick layer of skin

can provide satisfactory protection against the stresses of weight-bearing.

Kuhns *(21)* has reviewed our knowledge of elastic adipose tissue and has brought to our attention the detailed studies of Tietze *(40)* and Blechschmidt *(3)*. Kuhns shows that the stress-absorbing qualities of the subcutaneous layer in areas adapted to weight-bearing are due to its structure and to the elastic qualities of its connective tissues. In these areas the subcutaneous tissue consists of dense septa of elastic connective tissue which completely enclose spaces rilled with fat cells. Each such loculus is separate from its neighbour, and the fat cells within it are isolated from the surrounding loculi. In the heel pad, the fibrous septa extend from the dermis below and are attached above to the calcaneus posteriorly and to the plantar aponeurosis anteriorly. The flasklike spaces are filled with fat cells, and their walls are reinforced by oblique and spiral bands. These compartments, bounded by sheets of elastic fibrous tissue and filled with semifluid fat, act as hydraulic buffers. Under pressure they change form but not contents. When pressure is released, they resume their normal size and shape owing to the elasticity of the walls. A lateral radiograph of the heel, if not overexposed, often will reveal this fundamental structure of the subcutaneous tissue. The vertical septa of the relatively dense, elastic, connective tissue are readily seen extending upwards from the skin below to be attached above to the calcaneus posteriorly and to the plantar aponeurosis anteriorly (Figs. 16, 17, 18, 19, 20, 21, and 22).

It is important to preserve intact this specialized subcutaneous tissue in the heel flap of a Syme stump; otherwise the weight-bearing qualities will be impaired. To do so necessitates removal of the periosteum and the plantar aponeurosis with the heel flap, since these elements form the superior attachment of the septa. If the heel flap is dissected through the layer of subcutaneous tissue *(i.e.*, between the periosteum and the plantar aponeurosis above and the dermis below), the septa will be divided and the loculi opened, thus allowing the fat cells to leak out. In such circumstances, the distinctive structure and function of the elastic adipose tissue is lost,

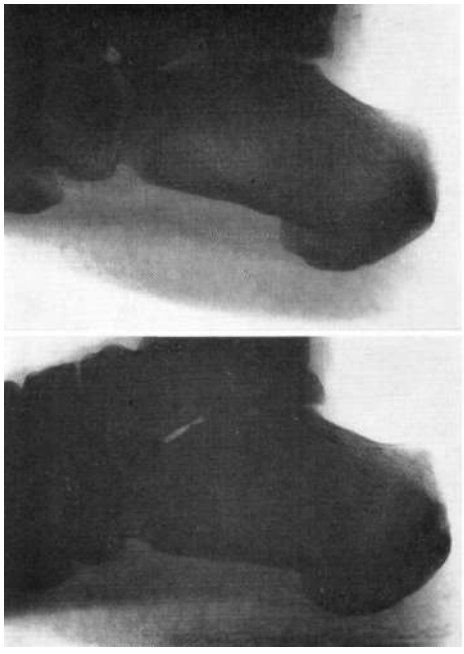


Fig. 16. Structure of the heel pad as revealed by radiograph. Top, without weight-bearing, bottom, patient standing.

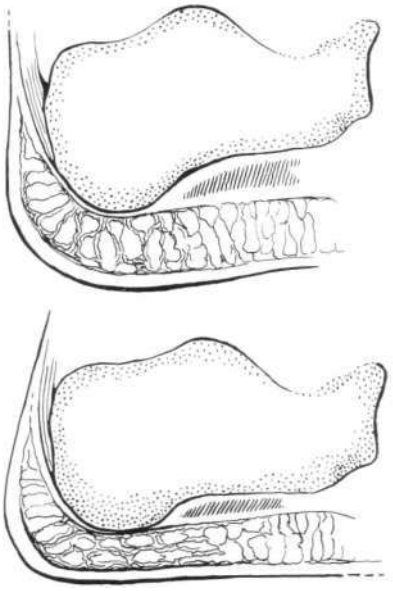


Fig. 17. Structure of the heel pad, diagrammatic representation reproduced from radiographs. Top, without weight-bearing; bottom, patient standing.

for then the tissue no longer consists of separate, elastic-walled spaces enclosing fat under tension. Once the elastic adipose tissue has been damaged, its stress-resistant properties cannot be restored.

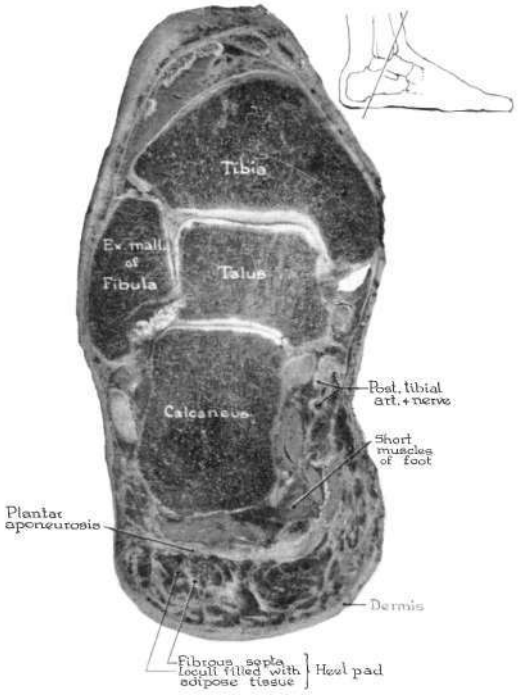


Fig. 18. Anatomy of the field of Syme's amputation. Insert shows the plane of the section.

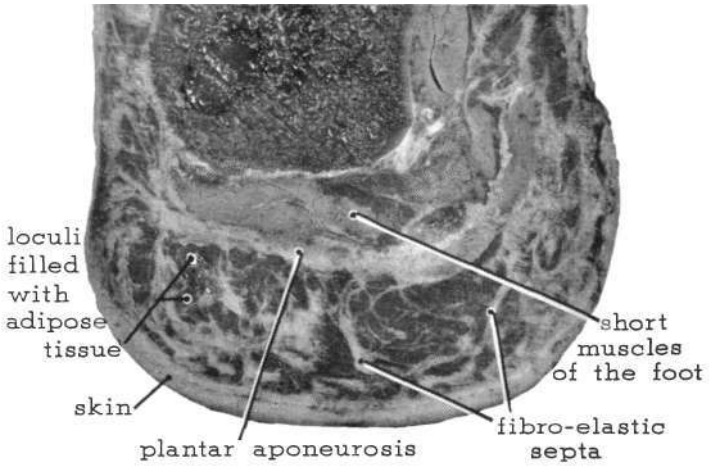


Fig. 19. Structure of the heel pad in Syme's amputation. Coronal section enlarged from Figure 18.

THE TECHNIQUE OF SYME'S AMPUTATION

In the five papers Syme wrote between 1843 and 1846 there is no complete and formal description of the technique of his operation, and there is only one inadequate illustration (Fig. 23). Scattered throughout the papers, however, are comments on various points in the procedure, and when the articles were gathered together and republished in the volume *Contributions to the Pathology and Practice of Surgery (36)* there was included an addendum concerned chiefly with certain details of the operation, particularly the technique for separation of the heel flap from the calcaneus. Therein, after emphasizing the desirability of "preserving entire the thick integuments of the heel to form a cushion for the stump," and after ascribing the known failures either to lack of skill in removing the flap from the calcaneus or to the use of flaps of skin other than that from the heel, Syme describes his technique as follows:

> The foot being placed at a right angle to the leg, a line drawn from the centre of one malleolus to that of the other, directly across the sole of the foot will show the proper extent of the posterior flap. The knife should be entered close up to the fibular malleolus and carried to a point to the same level on the opposite side, which will be a little below the tibial malleolus. The anterior incision should join the two points just mentioned at an angle of 45° to the sole of the foot and the long axis of the leg. In dissecting the posterior flap, the operator should place the fingers of his left hand upon the heel, while the thumb rests upon the edge of the integuments, and then cut between the nail of the thumb and the tuberosity of the os calcis so as to avoid lacerating the soft parts which he, at the same time, gently but steadily presses back until he exposes and divides the tendo achillis. The foot should be disarticulated before the malleolar projections are removed, which it is always proper to do, and which may be most easily effected by passing a knife around the exposed extremities of the bones and then sawing off a thin slice of tibia, connecting the two processes.

Scattered throughout the five papers are some other details worth noting. Syme found it important to avoid division of the posterior tibial

artery above its branching into the median and lateral plantar arteries; otherwise there was risk that the flap would slough. Separation of the heel flap, while not easy, could be accomplished satisfactorily by keeping close to the bone. The heel flap was not to be unduly large lest its circulation be impaired. Though Syme freed the heel flap before he dislocated the talus from the ankle joint, it was not long before surgeons were freeing the ankle joint first and dissecting the calcaneus from the heel flap downward from above, and this approach is part of our present procedure (*19*).

Fig. 20. Longitudinal section of foot to show structure of heel pad.

Today, when the problem of infection is not paramount, the purpose of the operation is, first, to remove the foot by disarticulation at the ankle joint and without damage to the specialized structure of the heel flap; second, to remove the malleoli and trim the lower ends of the tibia and fibula so as to provide a broad support for weight-bearing; third, to fashion from the heel a flap with unimpaired blood supply and with its weight-bearing mechanism undamaged; and, last, to secure this heel flap firmly and accurately to the lower ends of the tibia and fibula. The resulting stump should have a bulbous end to facilitate maintenance of the prosthesis on the stump. To meet these requirements, the skin incisions should be so designed as to give a heel flap of generous size but not so large that its blood supply will be impaired. This shape and size may be obtained by tilting the plantar incision slightly forward. Syme advocated a smaller heel flap because he feared necrosis from impaired circulation. Today, with the risk of infection removed, the larger heel flap, if carefully separated from the calcaneus, need not suffer from impaired circulation, and when sutured in place it has the advantage of overlapping and protecting the anterior margin of the lower end of the tibia.

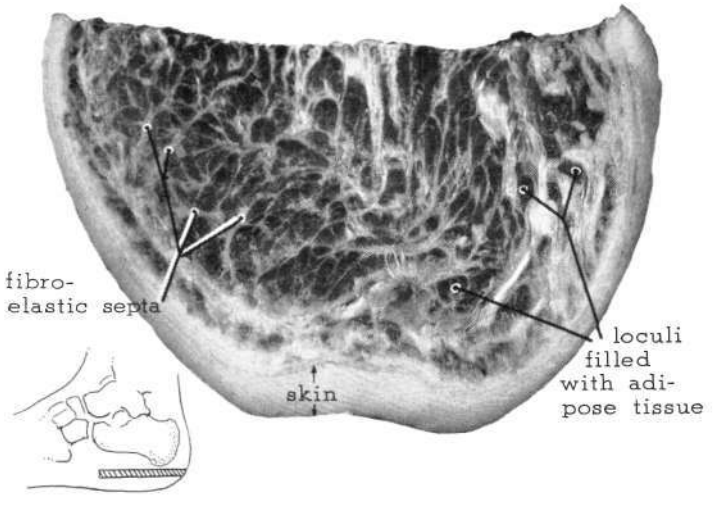


Fig. 21. Horizontal section through heel pad to show structure. This specimen is a slice of the heel pad cut parallel to the sole of the foot and midway between the skin and the inferior surface of the calcaneus. The skin surface is on the back and either side of the heel. Insert shows plane of section.

The lower ends of the tibia and fibula are fashioned with a saw cut which removes the medial and lateral malleoli and shaves off the articular surface of the tibia. The plane of this saw cut must be parallel to the ground when the patient stands (Fig. 24). That is to say, in all cases the tibia must be transected to suit the individual case and not necessarily in the same plane as the articular surface of the tibia or at right angles to the long axis of its shaft. The transection of the tibia and fibula must

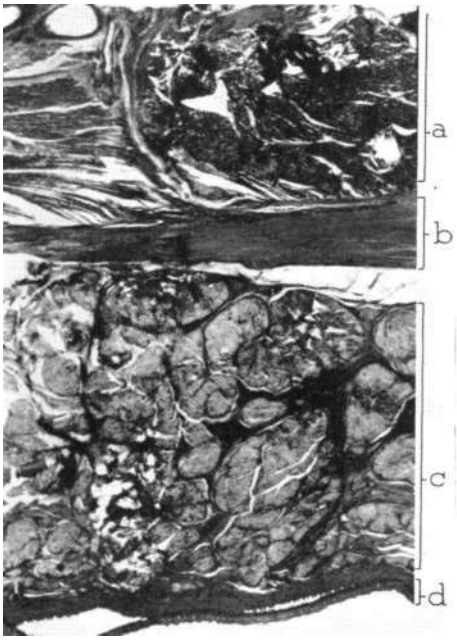


Fig. 22. Vertical section through heel flap, approximately 8X. *a,* Bellies of short muscles of foot; *b,* plantar aponeurosis; *c,* specialized elastic adipose tissue; *d,* skin.

be as low as possible to ensure that an area of support as broad as possible is obtained. With the modern type of Syme prosthesis, the resulting long stump presents no problem in fitting.

The fashioning of the heel flap and its proper attachment to the lower ends of the tibia and fibula are important steps in the operation. Preservation of the specialized fibroelastic subcutaneous tissue and the posterior tibial artery can best be assured by subperiosteal separation of the heel flap from the calcaneus. While this is a procedure somewhat more precise than that recommended by Syme (who advised that the flap be separated from the calcaneus by dissection with a sharp knife in a plane close to the bone), today with modern techniques and instruments it is easy to accomplish the desired result. The only step likely to give any difficulty is the detachment of the tendo achillis from the calcaneus, since in this situation there is no plane of cleavage. The tendon must therefore be divided carefully at its insertion close to the bone in order to avoid damage to the skin close behind it.

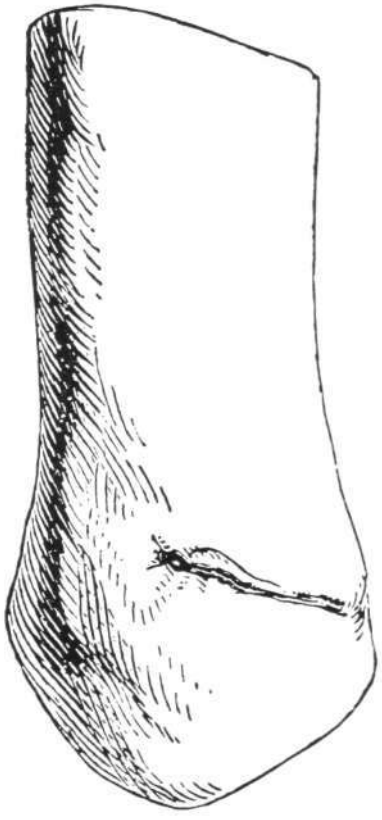


Fig. 23. The only illustration included by Syme in any of his publications on amputation at the ankle joint. It appeared in the *London and Edinburgh Monthly Journal of Medical Science (32),* with the following comment in the text: "The stump has the shape here represented, conical in form on the inferior surface and having for its apex, or central point of pressure, the thick integument which covered the heel." This illustration was not included when the five papers *(30, 31, 32, 33, 35)* on *Amputation of the Ankle Joint* were reproduced in *Contributions to the Pathology and Practice of Surgery (36).*

Subperiosteal dissection of the calcaneus from the heel flap has one advantage not envisioned by Syme. Besides preserving the posterior tibial artery and the weight-bearing structure of the heel, it leaves a heel flap lined with periosteum, which more readily and more firmly adheres to the cut surfaces of the tibia and fibula. Henry Thompson *(39)* must have had something of this nature in mind when he advocated leaving a flake of the os calcis in

the heel flap. As can be seen in radiographs (Figs. 25 and 26), new bone sometimes forms from the periosteal lining of the heel flap, in which case there is very firm fixation of the heel flap to the tibia and fibula. In this connection, it is interesting to note an observation of Jacobson (*19).* In discussing Syme's amputation, he describes the technique of removal of the calcaneus from the heel flap by an approach from above:

> The foot being still more pressed *(i.e.,* downward to dislocate the talus from the ankle joint), the upper nonarticular surface of the os calcis comes into view and then the tendo achillis. This is severed and the heel flap next dissected off the os calcis from above downwards, special care being taken to cut this flap as thick as possible, not to score or puncture it, but rather to peel it off the bone with the left thumb nail kept in front of the knife aided by touches of this.

Thereto is appended a footnote:

> If, in a young subject, the epiphysis comes away in the heel flap, it may remain there if the parts are healthy. *The same course may be followed with the periosteum if it is found loose and peels away.* Mr. Johnston Smith, when amputating both feet for frostbite, left the periosteum on one side; on the other no attempt was made to save it. The first stump was much larger than the other, harder and more rounded, more like that of Pirogoff's amputation.

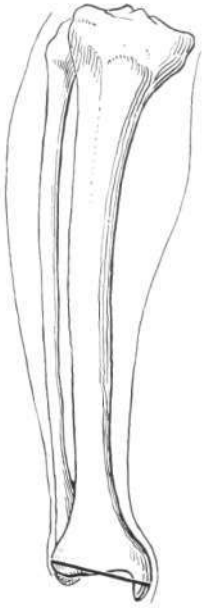


Fig. 24. Proper saw line for Syme's amputation, when tibia is abnormal or deformed. The plane of section of the lower ends of tibia and fibula is not necessarily that of the inferior articular surface of the tibia but must in all cases be parallel to the ground when the patient stands erect. When for example the tibia is bowed, as represented here, the plane of section is horizontal and not at 90 degrees to the long axis of the bone.

Published in 1889, this comment preceded introduction of the roentgen ray. In all respects, save the radiographic proof, it indicates clearly that subperiosteal separation of the heel flap results in more firm attachment of flap to the tibia and fibula than is the case when the periosteum is not preserved.

When stresses come upon a heel flap not firmly attached to the cut surfaces of the tibia and fibula, it wobbles and thus loses some of its functional value. Moreover, the tendo achillis and the peroneal tendons buried therein drag the heel flap this way or that when they contract (Figs. 27 and 28). Both of these problems can be eliminated by subperiosteal separation of the calcaneus from the heel flap, for doing so ensures firm fixation of the flap to the cut ends of the tibia and fibula.

A heel flap which has been formed by subperiosteal dissection from off the calcaneus is clumsy and untidy in appearance. It is a deep, cup-shaped structure covered with thick skin and rendered bulky at its anterior end by the

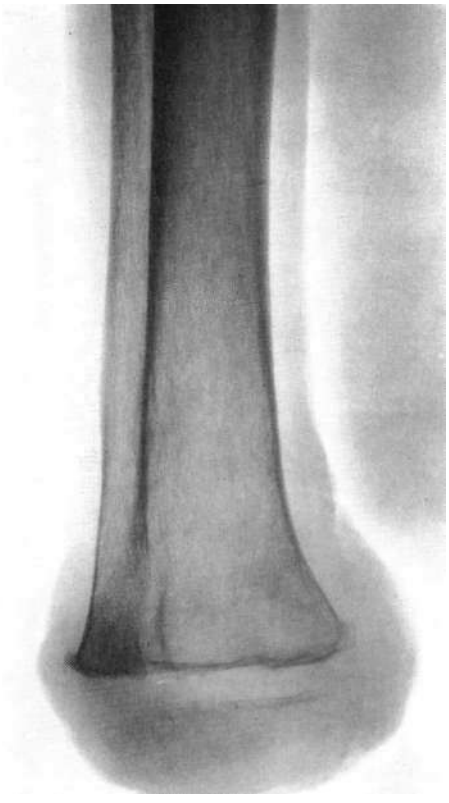


Fig. 25. A flake of new bone laid down in the heel flap of a Syme stump, the result of subperiosteal separation of the heel flap from the calcaneus. Firm fixation of the heel flap to the cut surfaces of the tibia and fibula is thus ensured.

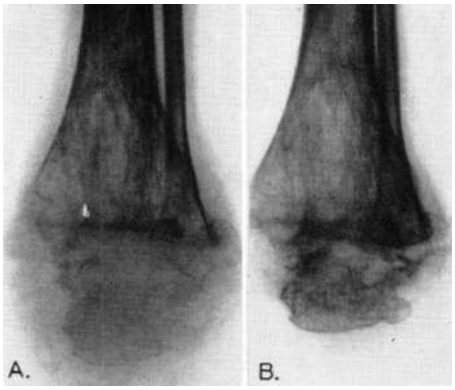


Fig. 26. A large mass of bone laid down in the heel flap of a Syme stump. *A,* four months after operation; *B,* one year after operation. This unusually large cloud of new bone resulted from the stimulation of the periosteum by the inflammatory reaction to tuberculosis of the tarsus, the reason for the amputation.

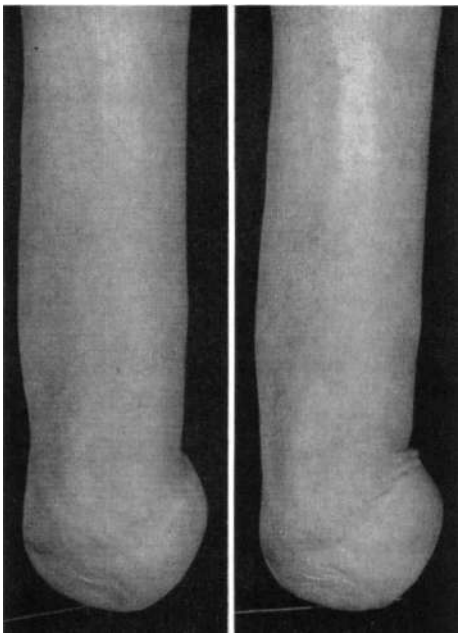


Fig. 27. Misplaced and unstable ("wobbly") heel flap, the result of tidying up the heel flap by removal of the stumps of the short plantar muscles and with them the plantar aponeurosis and the periosteum of the calcaneus. The result is a heel flap imperfectly fused to the end of the tibia and in bad position. Left, muscles at rest and heel pad held as nearly as possible under the tibia by elastic traction; right, contraction of peroneal muscles drags the unstable heel flap toward the lateral side of the stump.

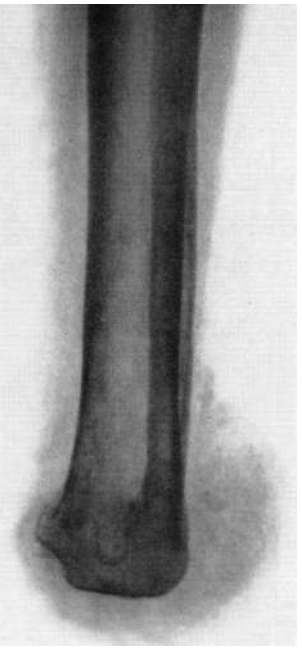


Fig. 28. Radiograph of the imperfect Syme stump shown in Figure 27. In addition to the unstable and misplaced heel flap, the high level of transection of the tibia and fibula limits the area available for support. In spite of these defects, the stump has functioned reasonably well for 12 years.

inclusion of the bellies of origin of the short plantar muscles. The instinct of every meticulous surgeon is to tidy it by removal of these bulky muscle stumps, but it is best to leave them in place. They do no harm, and any attempt to remove them may damage the specialized, weight-bearing, subcutaneous tissue by removing with them the plantar aponeurosis, from which the fibrous septa originate.

The detailed steps (Figs. 29, 30, 31, and 32) in the operation as at present performed are as follows:

1. Apply an air-pressure tourniquet to the thigh.

2. With the foot at a right angle to the tibia, make two incisions: First, from the tip of the lateral malleolus, across the sole of the foot to a point just below the tip of the medial malleolus, the cut being made through all the soft tissues directly down to the tarsal bones. At its center, this plantar incision should be curved slightly forward from the tips of the malleoli, rather than the reverse, so that the center of the flap will be elongated to facilitate covering the anterior margin of the cut sur-

face of the tibia when the wound is closed. Second, a dorsal incision joining the upper ends of the plantar incision and running upward and forward at an angle of 45 deg. from the line of the tibia and from the plantar surface of the foot. It bisects the angle between the tibia and the foot. Through it the ankle joint is entered.

3. With the ankle joint open, plantar flex the foot and divide the tibial and fibular collateral ligaments of the ankle from within the joint. On the medial side, be careful to avoid the posterior tibial artery.

4. Dislocate the talus downward from the mortise of the ankle joint, open the posterior part of the capsule of the ankle joint from within, and expose the posterosuperior nonarticular surface of the calcaneus and the anterior surface of the tendo achillis just above its insertion.

5. With a periosteal elevator (Bristow raspatory), enter the subperiosteal plane on the medial and lateral sides of the calcaneus and extend this subperiosteal dissection to the inferior surface of the bone. Tilt the foot first into inversion and then into eversion and continue the subperiosteal freeing of the calcaneus on its inferior surface. Then work forward in the subperiosteal plane on the medial, lateral, and inferior surfaces of the calcaneus. Detach the origin of the long plantar ligament from the tuberosity of the calcaneus, and continue in the subperiosteal plane until the plantar skin incision is reached and the anterior end of the bone is free. Work backward in the subperiosteal plane until the whole of the calcaneus is free except at the insertion of the tendo achillis. With a knife, carefully divide the tendo achillis working downward from above. Stay close to the bone and avoid damaging the skin flap behind the tendo achillis. Remove the talus and calcaneus together with the damaged portion of the foot. If this step is accomplished successfully, the posterior tibial artery will be unharmed. Only its plantar branches will have been cut by the primary plantar incision. Do nothing to the posterior tibial nerve, which also will have been cut by the primary plantar incision.

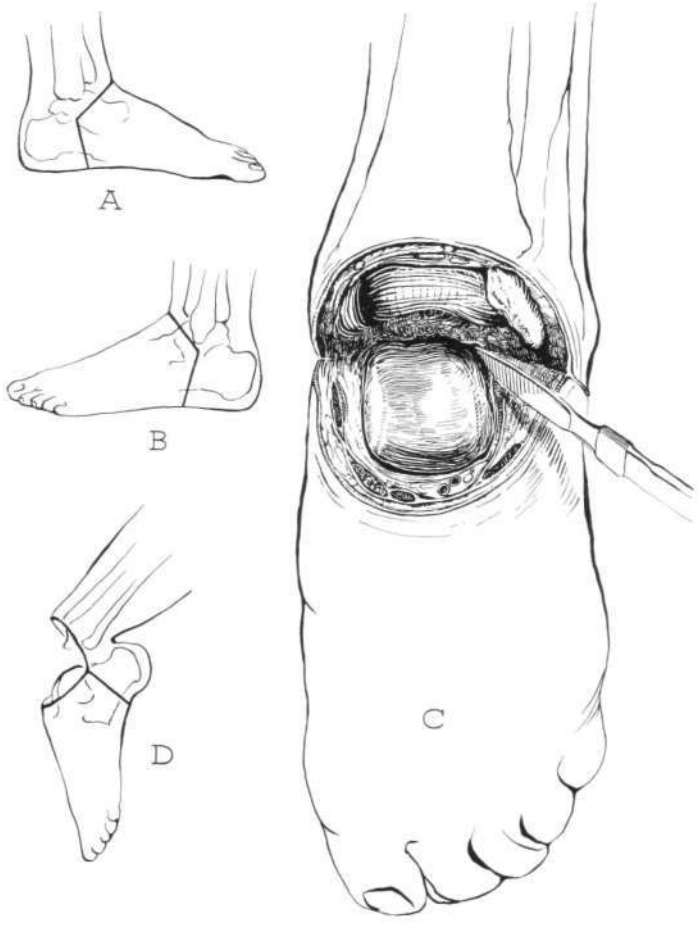


Fig. 29. Technique of the Syme amputation. *A,* Skin incisions from the medial side; *B,* skin incisions from the lateral side; C, division of the collateral ligaments from within the joint; *D,* dislocation of the talus downward from the mortise of the ankle joint.

6. Carefully turn the heel flap backward and upward, and free the malleoli and the lowest 1/4 in. of the tibia. Remove the malleoli and a thin slice of the lower end of the tibia by a saw cut. Be certain that the saw cut will be parallel to the ground when the patient is standing. The amount of tibia removed should be the thinnest possible shaving from its lower end, the subarticular cortical plate being conserved if possible. In any case, be certain that the largest possible cross-sectional area of the tibia and fibula is obtained to ensure a broad area of support (Fig. 33).

7. Remove the tourniquet and secure perfect haemastasis. Do not trim the heel flap, much as you may desire to make it tidy.

8. With interrupted sutures of chromic catgut #0 for the subcutaneous layer and interrupted everting mattress sutures of braided nylon for the skin margins, suture the margin of the heel flap to the margin of the anterior incision across the front of the ankle joint. Suture nothing but the subcutaneous layer and the skin. To drain the dead space, enclose across the wound a section of Penrose tubing and allow the ends to come out

at either corner of the wound. The line of suture should be slightly above the anterior margin of the cut surface of the tibia so that cut ends of the bones fit into the cup of the heel flap.

9. In closing the wound, pay no attention to the disparity in size, shape, and thickness between the heel flap and the skin margin to which it will be sutured. Center the hollow of the heel flap beneath the cut ends of the tibia and fibula as accurately as possible, and begin the suture line in the center anteriorly and work to either end. Do nothing to the "dog ears" of skin which project at the corners of the approximated skin margins. In time they will shrink and disappear. To trim them invites impairment of circulation.

10. The heel flap thus sutured is attached only at its margin and is not yet fixed firmly to the cut surfaces of the tibia and fibula, and accordingly it can be moved about in relation to them. It needs to be secured and maintained in a proper position. To do so, hold the heel flap accurately centered beneath the cut surfaces of the tibia and fibula and secure it in this position by two strips of adhesive tape fastened U-shaped across the end of the stump in the anteroposterior and mediolateral directions (Fig. 32). Adhesive tape is better than pins transfixing the heel pad to the tibia, as has sometimes been advocated. Do not apply the adhesive strips too tightly.

11. Dress the wound with two layers of surgical pads smoothly applied and held in place by a mildly compressive bandage. Flannelette cut on the bias is ideal, although cotton-crepe bandage (without elastic) will do if not applied tightly.

12. *Important.* Open the dressing 24 hours after the operation and every second day thereafter, and inspect the position of the heel flap in relation to the lower ends of the tibia and fibula. Adjust or renew the adhesive strips if necessary to maintain the correct position of the heel flap. If the operative dressing is left unchanged, the heel flap may unite asymmetrically. The stump must be inspected frequently in the postoperative period, and adjustments of the position of the heel flap must be made when necessary. Remove the Penrose tube about the sixth day.

13. Maintain a firm dressing until the wound is healed and the stitches are removed (about two weeks). Support the stump thereafter with a cotton-crepe elastic bandage until the first limb is fitted. At the end of four weeks, the patient may begin to put weight on the end of the stump. A prosthesis may be fitted at the end of two months, though it will require a new socket within a year, when shrinkage of the calf muscles is complete.

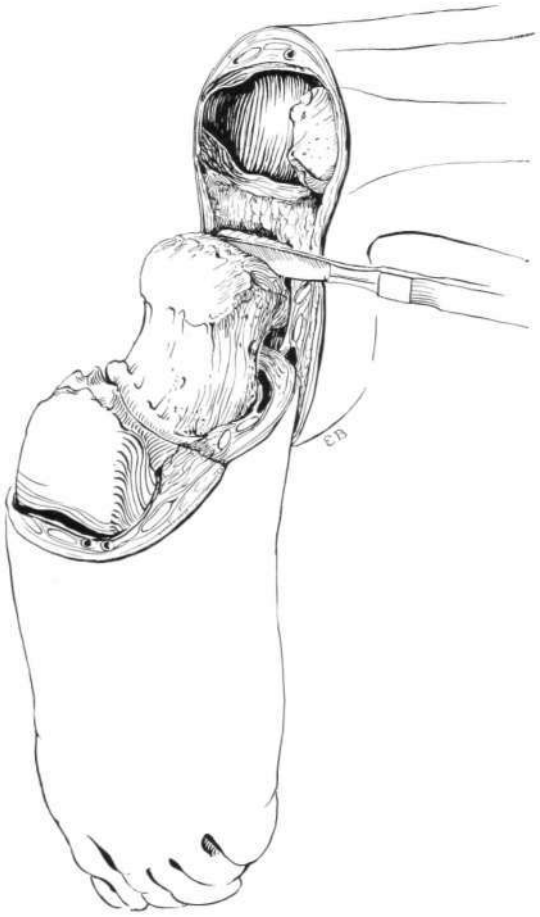


Fig. 30. Technique of the Syme amputation, continued. The talus has been dislocated from the ankle joint. The calcaneus has been separated almost completely from the heel flap by subperiosteal dissection. The tendo achillis is about to be divided at its insertion.

IMPERFECTIONS WHICH IMPAIR THE FUNCTION OF THE SYME STUMP—How TO AVOID OR CORRECT THEM

Not all Syme stumps are perfect, but nearly all imperfections can be avoided by meticulous attention to the details of the operation. Too much emphasis cannot be placed upon a proper understanding of the principles of the amputation and upon its proper performance. Although some imperfections can be compensated for in the fitting of the prosthesis or in the manner of its use, and although some can be eliminated by revision operations, others cannot be overcome at all, usually because of faulty performance of the initial operation.

DAMAGE TO THE WEIGHT-BEARING STRUCTURE OF THE HEEL FLAP

A serious imperfection, which cannot be corrected by further operation, is damage to the weight-bearing structure of the heel

flap. This is almost always due to the manner in which the operation is performed. Care must be taken to preserve intact the specialized subcutaneous fibroelastic tissue of the heel pad. As previously indicated, this can be accomplished most certainly by attention to two details in the operation: subperiosteal separation of the heel flap from the calcaneus and avoidance of any attempt to tidy the clumsy flap by removing the stumps of origin of the small muscles of the foot. If these steps in the operation are properly performed, the specialized subcutaneous tissue will remain intact and its function will be unimpaired. On the other hand, if the plane of the subcutaneous tissue is entered during the operation, there will be more or less impairment of its structure and function. This is the prime example of the necessity to perform Syme's amputation by a technique which adheres rigidly to the basic principles of anatomy. There is only one opportunity to fashion a Syme stump of the best quality and that is the occasion of the primary operation. If this is performed skillfully and with due regard for basic principles, it will produce a good end-bearing stump. If the basic principles are disregarded, or if the operation is performed carelessly, the weight-bearing qualities of the flap are likely to be impaired, and they cannot be restored by any subsequent operation.

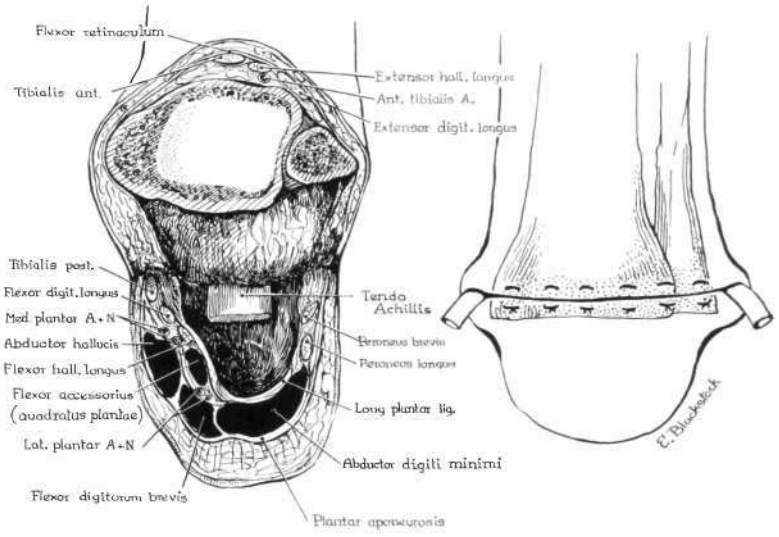


Fig. 31. Technique of the Syme amputation, continued. Left, the anatomy of the field of operation after the tarsus has been removed from the heel flap; right, closure of the wound with drainage.

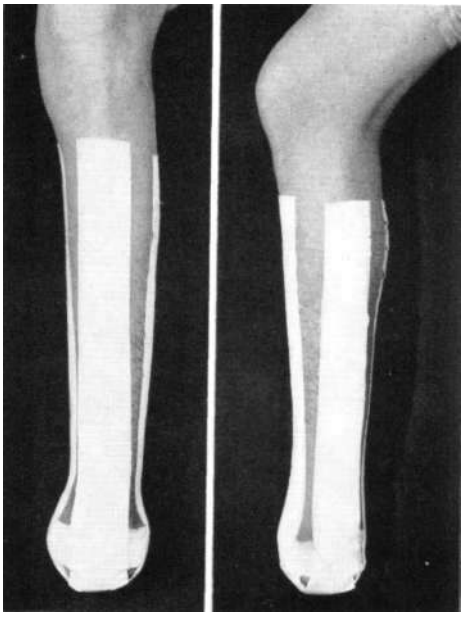


Fig. 32. Technique of the Syme amputation, continued. The method of strapping the heel flap to the leg to ensure that its position in relation to the cut ends of the tibia and fibula is exactly correct and will remain so.

While a defective Syme stump deprives the patient of the comfort and good function he would enjoy with a perfect stump, it may still be sufficiently useful to make it worth while retaining. Reamputation at a higher level is not always inevitable *(28).* Even an imperfect Syme stump may be more useful than a below-knee amputation. Therefore reamputation at a higher level because of an imperfect Syme stump should be undertaken only after the most careful consideration of every aspect of the problem.

Besides damage to the heel flap, and consequent impairment of the weight-bearing

Fig. *33.* Oblique transection of lower end of tibia results in displacement of heel pad to high side. *A,* The stump when no weight is upon it; the heel pad is displaced medially. *B,* Radiograph of stump; tibia transected obliquely, higher on the medial than on the lateral side. *C,* The stump bearing weight; the heel pad is markedly displaced to medial side. The function of this heel flap (which already is unstable and misplaced) is impaired still more by the displacement which occurs when weight is borne upon it. This is the result of oblique section of lower end of tibia.

qualities of the stump, a number of other faults can impair the functional value of a Syme amputation.

MISPLACED HEEL FLAP

Care must be taken to secure the heel flap beneath the tibia in such a manner that the plantar surface of the flap is exactly beneath the center of the lower end of the tibia. To keep it there necessitates painstaking care and supervision during the immediate postoperative period. The heel flap being a large, cup-shaped structure, loosely attached to the leg, it must be secured in its proper position by adhesive strips and maintained so until healing has fixed it to the lower end of the tibia (Fig. 32). If postoperative inspection is neglected, the heel flap may be pushed out of place by the dressing and may unite to the tibia displaced to one side or the other or backward. Its end-bearing capability is then impaired. Fortunately, if the specialized fibroelastic adipose tissue has not been damaged, malposition of the heel flap can be corrected by detaching it and replacing it in its proper position.

SLOPING SURFACE OF LOWER END OF TIBIA

If the cut surface of the lower end of the tibia is not parallel to the ground when the patient stands, the heel flap tends to be pushed to the high side of the slope (Fig. *33).* The plane of transection must therefore be parallel to the ground when the patient stands no matter what its geometric relationship to the long axis of the tibia. If there is any bowing or other deformity of the tibia, the proper plane of transection may actually be oblique to the long axis (Fig. 24). The particular circumstances in the individual case must be assessed at the time of the primary operation to make certain not only that the plane of section of the lower surface of the tibia is parallel to the ground but also that the maxi-

mum area of bony support for the heel flap is secured (Fig. 34). Any operation to revise an improper bearing surface must necessarily be at a higher level where the cross-sectional area for support is smaller (Fig. 24).

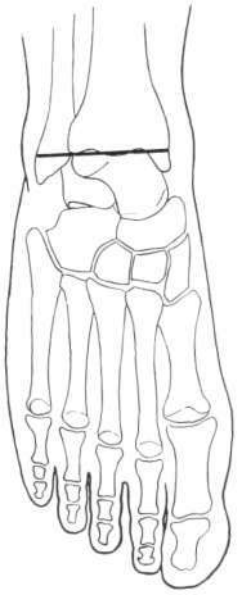


Fig. 34. The proper level for transection of the tibia and fibula in Syme's amputation.

"WOBBLY," OR UNSTABLE, HEEL FLAP

If the heel flap is loosely attached to the lower end of the tibia, it is easily displaced, and pressure while walking or standing may wipe it to one side or the other or backward. Similarly (Figs. 27 and 28), it may be pulled out of place by the stumps of the tendons that are embedded in it, the tendo achillis and the peroneal tendons being the chief offenders. Because the thrust of weight-bearing cannot be maintained through the center of the flap, even when the prosthesis is snugly fitted, an unstable heel flap does not bear weight satisfactorily. The anterior margin of the lower end of the tibia presses through the scar of the anterior suture line, and the patient stands insecurely upon the shifting end of his stump. A flaccid, loose, heel flap occurs when the plane of separation is through the subcutaneous elastic adipose tissue. It can be prevented by subperiosteal dissection of the heel flap. The deep surface of the flap then attaches itself firmly to the cut surface of the bone, and the intact pad of weight-bearing subcutaneous tissue resists changes in shape. An unstable heel flap can be avoided only by proper operative technique. Once it exists it cannot be corrected by further operation though its shortcomings may be minimized by modifying the fit of the prosthesis.

NEUROMA ON POSTERIOR TIBIAL NERVE

In the surgery of the Syme amputation, no attempt should be made to free the posterior tibial nerve and divide it at a high level lest so doing lead to damage of the adjacent posterior tibial artery and consequent impairment of the blood supply to the heel flap. Although a neuroma inevitably develops at the cut end of the nerve, it seldom gives trouble. In the rare case in which the neuroma is sensitive, a cure can be effected by late transection of the nerve at a level well above the ankle joint but without removal of the distal segment of the nerve.

MARGINAL GANGRENE OF THE HEEL FLAP

Except in cases of peripheral vascular disease, marginal gangrene of the heel flap is nearly always due to faulty operative technique. Either the blood supply to the flap is impaired by injury to the posterior tibial artery, or the dressings are put on too tightly, or swelling occurs beneath the adhesive strips and they are not loosened soon enough. With care in operating, there is little danger of necrosis of the flap. Should necrosis occur, the stump is not necessarily ruined unless the loss of tissue is very great (Figs. 35, 36, and 37).

VASCULAR INSUFFICIENCY IN THE HEEL FLAP

It has been said that the great length of a Syme stump results in vascular insufficiency manifested by a cold, blue, painful stump end, symptoms which are greatly accentuated in cold weather. There has been no such experience in Canada, where, in winter, many of the patients are exposed to very low temperatures. Experience leads to the conclusion that vascular stasis from exposure to cold is not a problem of any importance in the Syme amputation.

TENDER HEEL FLAP WITH CALLUSES

A calloused and tender heel flap is almost always due to failure to preserve the specialized fibroelastic adipose tissue. It is accentuated if the area of transection of the tibia and fibula is small or if there are projecting bone spurs. The problem can be prevented by proper fashioning of the heel flap and by division of the tibia and fibula low enough to provide a broad area of support. If bony spurs are present, they should be removed, but neither a damaged heel flap nor an inadequate area

of support can be corrected by any subsequent operation.

IMPERFECT SKIN COVERING OF THE STUMP

In an occasional Syme stump the end is covered with skin ill adapted to weight-bearing. Usually in such cases the extent of the original trauma was such as to leave very little material from which to fashion an adequate heel flap. Sometimes the heel flap is scarred by wounds or infection. Some of the heel flap may have been lost by vascular damage, or the original covering of the stump may have been skin from a site other than the heel. Though little can be done to improve such stumps by further operation, modification of the prosthesis so as to distribute the weight between the end of the stump and the upper end of the socket, as in a below-knee prosthesis, offers promise of improvement. Despite the great importance of covering the end of the stump with skin and subcutaneous tissue accustomed to weight-bearing, there is reason to believe that, when the cut surfaces of the tibia and fibula are as broad as possible, the stresses of weight-bearing are distributed so widely that even ordinary skin and subcutaneous tissue can sometimes function satisfactorily (Fig. *38).*

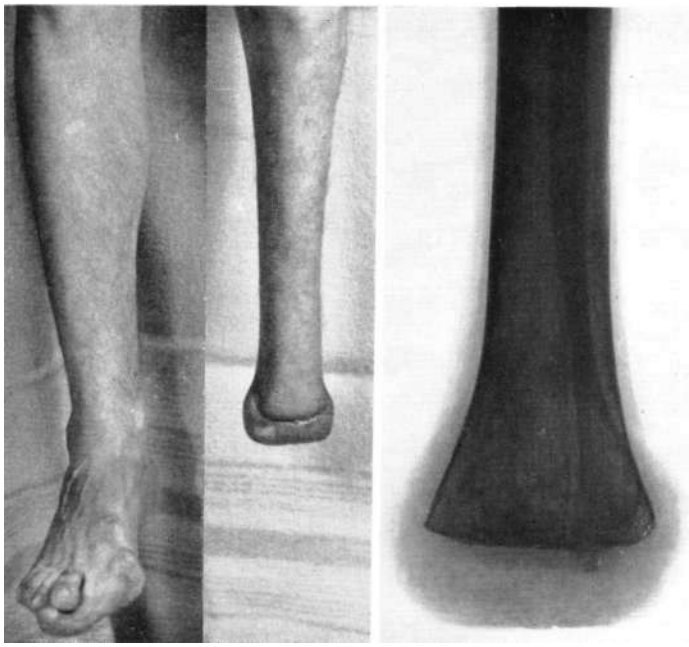


Fig. 35. Salvage of a Syme stump in spite of marginal gangrene of the flap. This 38-year-old man suffered ischemic necrosis of the muscles of his leg as a complication of fracture of the femur when he was eight years old. He slowly developed a grossly deformed, insensitive foot with trophic ulceration. When the Syme amputation was performed, the posterior tibial artery was inadvertently divided. The result was marginal gangrene of the flap. Separation of the gangrenous margin occurred slowly over a period of eight months. During that time the flap was held in place by adhesive strapping and carefully applied dressings. Wearing an "elephant prosthesis" (Fig. 36), he first walked five months after his operation. The scar is depressed at the line of suture as the result of the separation of the gangrenous margin of the heel flap. Left, appearance of stump; right, radiograph of stump.

INDICATIONS FOR SYME'S AMPUTATION

With a technique that ensures a satisfactory end-bearing stump, Syme's amputation is indicated for all destructive, infective, or other disabling lesions of the foot that cannot be dealt with by a transmetatarsal amputation. The skin over the heel must be intact. Syme's amputation should replace Lisfranc's and Chopart's whenever these amputations are apt to be unsatisfactory, as is often the case. The following are the principal conditions for which Syme's amputation is most frequently performed.

SEVERE INJURIES OF THE FOOT

Compound and comminuted fractures of the tarsus and metatarsus and crushing injuries of the foot are usually best treated by Syme's amputation. If damage to the skeleton of the foot is severe, it is often impossible to salvage a useful and painless foot. As soon as this circumstance becomes apparent, or if from the beginning it is obvious that much of the foot must be lost by reason of the injury or that the foot will ultimately become deformed, rigid, and painful, a Syme's amputation is indicated. It should be performed as soon as the risk of infection can be eliminated.

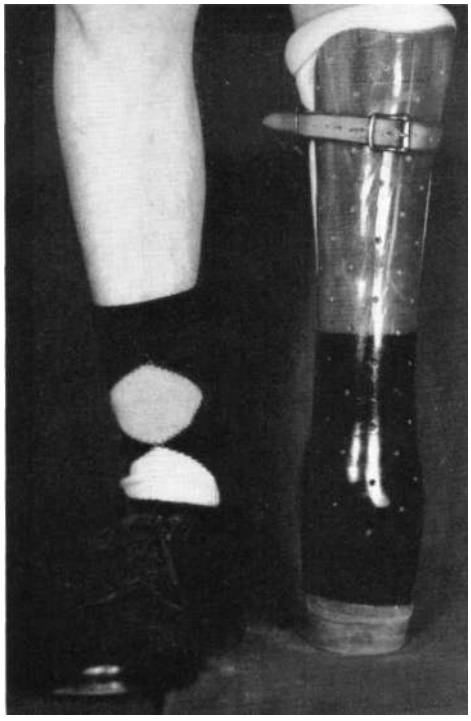


Fig. 36. The temporary "elephant prosthesis" used on the patient shown in Figure 35. It enabled him to walk during the long period of wound-healing.

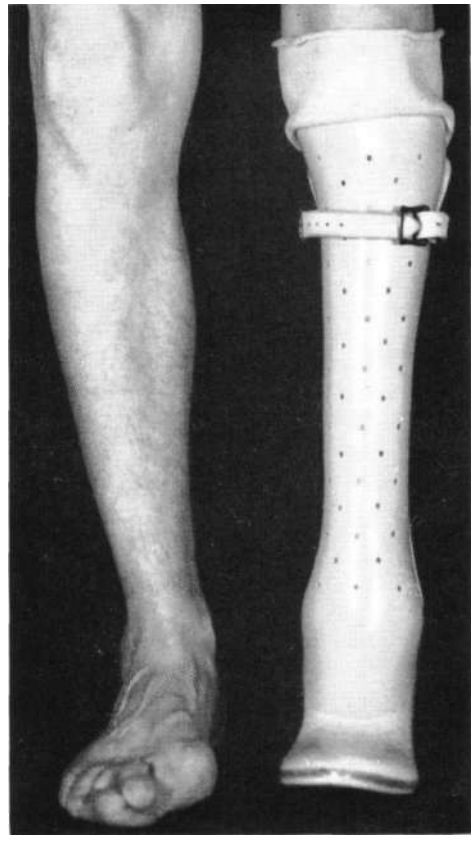


Fig. 37. The final prosthesis provided the patient shown in Figure 35. See pages 52-75.

With antibiotics available, the amputation can sometimes be performed as a primary measure. More frequently it will be wise to perform it as a secondary procedure after infection has been brought under control and the wound has healed or nearly healed. In dealing with injuries to the foot, especially war injuries, the advantages of the Syme amputation should be borne in mind so that, instead of immediate resort to a mid-tibial amputation, a two-stage operation can be planned, the primary stage being to remove the shattered and infected distal portions of the foot while preserving the heel flap, the second to effect a formal Syme amputation after the wound has healed or after infection is under adequate control.

INTRACTABLE INFECTIONS OF THE BONES AND JOINTS OF THE FOOT

Today infection is less often an indication for Syme's amputation than it was formerly. Antibiotics give us such control over infections (including tuberculosis) that amputation is seldom necessary as a life-saving measure. It still has a place in the eradication of persistent, chronic infection and in the management of a few unusual infections, such as blastomycosis. Syme's first operation was for tuberculous infection of the talus and calcaneus. It is a tribute to the operator that in a day of uncontrolled infection the result was completely successful.

DEFORMITIES OF THE FOOT

Foot deformities that cause serious disablement from rigidity and localized pressure and that are incapable of correction are indications for Syme's amputation. Although the chief cause of such deformities is previous trauma or infection, conditions such as old clubfoot with intractable deformity can also be well treated by Syme's amputation.

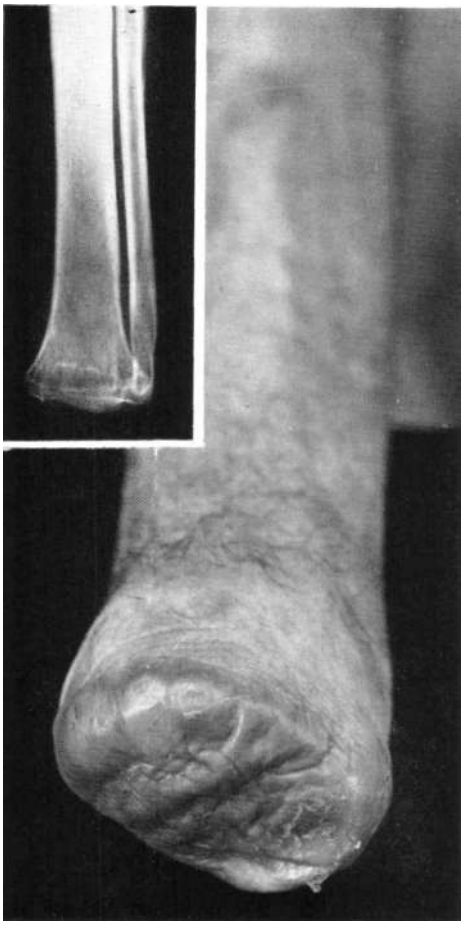


Fig. 38. A modified Syme amputation in which, because of an injury that completely destroyed the heel flap and the calcaneus, the transected ends of the tibia and fibula were covered with a flap from the dorsum of the foot. Photo shows stump 10 years after amputation, never any trouble; insert is a radiograph showing broad area of support, which probably accounts for the success of this stump despite lack of covering with normal heel pad. Similar to Baudens' supramalleolar amputation (2).

WAR INJURIES

Because battle wounds commonly cause gross damage to tissues, and because they must often be treated hastily, in large numbers, and usually under conditions less than ideal, the merits of Syme's amputation must be emphasized lest the soldier be deprived of its advantages. Every war injury of the foot should be regarded as a condition that might ultimately best be treated by Syme's amputation. Even in questionable cases, consideration should be given to a two-stage procedure: first, removal of the damaged parts with concomitant control of infection; second, a formal Syme amputation when healing of the first wound is well along.

FROSTBITE AND IMMERSION FOOT

Extreme cold causes thrombosis of the smaller vessels of the foot, especially of the distal portions, so that gangrene of the toes develops in severe cases. Foot damage from frostbite, if of considerable extent, is well treated by Syme's amputation. Less severe cases may recover without amputation, or escape with amputation of the toes, or with transmetatarsal amputation.

SELECTED CASES OF OBLITERATIVE VASCULAR DISEASE

Contrary to expectation, it has proved possible to deal with certain cases of Buerger's disease and of arteriosclerotic vascular disease by Syme's amputation. Buerger's disease is more often suitable for Syme's amputation than is arteriosclerotic vascular disease. The most suitable case is a young or middle-aged man suffering from obliterative disease with gangrene of the toes and neighboring parts and a favourable response to lumbar sympathetic block. In such cases, a lumbar sympathectomy, followed by Syme's amputation, will often provide a useful stump that will last for years. Dr. Gordon M. Dale (P), who has had considerable experience with the Syme amputation for obliterative vascular disease (page 44), has had success in 50 percent of his cases. The Syme stump has provided much better function than would have been possible with amputation at a higher level, a matter of special importance since these patients constantly face the possible loss of the other leg at a later date for the same disease *(45).*

CERTAIN NEUROLOGICAL LESIONS

Neurological diseases occasionally produce in the foot changes which impair its usefulness and which may transform it into an encumbrance. If infection supervenes, the patient's life may be endangered.

Neuropathic joints in the foot can develop

from tabes dorsalis, syringomyelia, or Charcot-Marie-Tooth neuromyopathy. If the disability and deformity from these problems is severe, a Syme amputation is a valuable procedure. It removes the damaged joints and provides the patient with a useful end-bearing stump.

The sensory loss which accompanies irreparable sciatic-nerve lesion or spina bifida is prone to result in trophic lesions of the skin of the sole of the foot. These skin lesions occur most frequently in the anterior portion of the foot, where the metatarsal heads press unduly upon the skin which underlies them. When ulceration of the skin develops, infection follows. It must be quickly and completely eradicated. The skin beneath the heel is less often involved because of the thickness of the heel pad. The ulcers beneath the metatarsal heads are so situated that a transmetatarsal amputation is seldom possible because the skin available is inadequate to cover the end of the foot without tension. Such cases are well treated by Syme's amputation.

Fig. 39. The Syme amputation in children. This 18-year-old boy suffered embolism or thrombosis at the bifurcation of the aorta as a complication of septicaemia at the age of seven years. Gangrene of his right toes and of the left foot occurred. A Syme amputation was performed on the left foot in May of 1948. He has had a perfectly satisfactory stump for 11 years. Left, the stump (in 1958) shows a large heel pad which moves rather loosely on the ends of the bones; right, radiograph of the stump showing that the transection was rather high. The left tibia is 2 1/8 in. shorter than the right. There is no projection of the bone ends through the end of the stump.

SYME'S AMPUTATION IN CHILDREN

Syme's amputation can be utilized in children as successfully as in adults, especially in the treatment of destructive foot injuries and of certain congenital foot deficiencies and deformities. Indeed, if properly performed it has in children two special advantages not applicable to adults. Provided the lower epiphyseal line of the tibia is preserved intact, the growth in length of the tibia is but little diminished. Secondly, progressive growth does not project the lower ends of the bones through the skin, as happens all too frequently when amputation through the shaft of the tibia is performed in early childhood.

The chief indications for the operation in children are trauma that results in irreparable damage to distal parts of the foot, vascular accidents that terminate in ischemic necrosis or gangrene of the toes and associated parts, and congenital deficiencies and deformities that result in a foot so imperfect as to be an encumbrance. It is of importance that the lower epiphyseal line of the tibia be undamaged and that an area of support as broad as possible be obtained. In children, accordingly, little more should be done to the bones than to remove the malleoli. The lower articular surface of the tibia is left untouched, while the calcaneus is removed from the heel flap by subperiosteal dissection.

The Syme amputation can be performed in children as early as the second or third year, with great benefit to the patient. Even if it does nothing more than postpone a formal, mid-tibial amputation until growth has ceased,

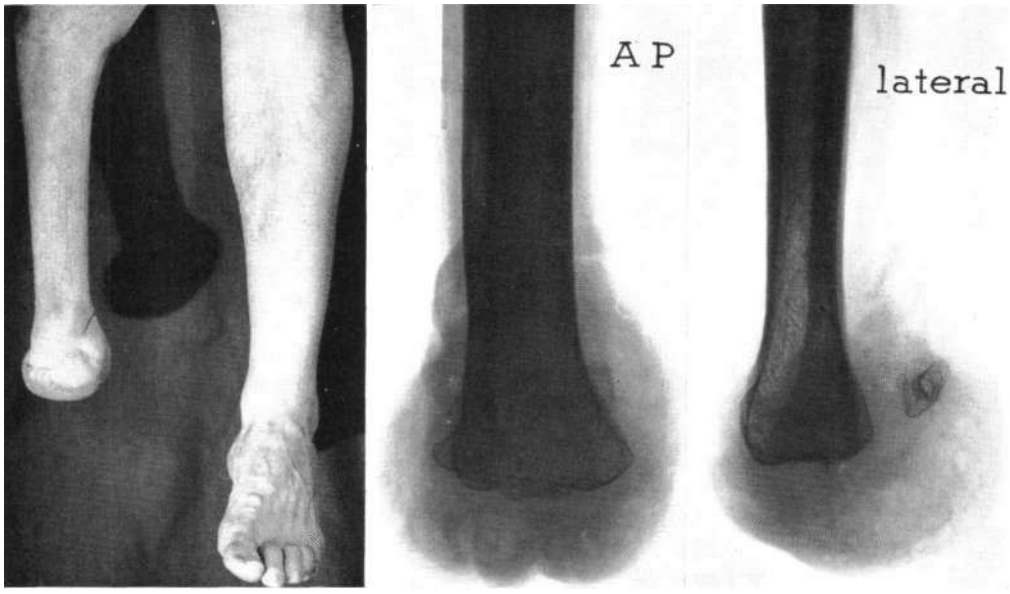


Fig. 40. Lower extremities of a 70-year-old man whose Syme amputation was performed 65 years ago for deformed foot resulting from a severe injury at the age of two. Left, appearance of the stump; right, radiographs of the stump. The heel flap is large and soft, moves rather freely on the ends of the bones, and can be moved voluntarily by contraction of the tendo achillis. There is very little shortening of the tibia. Patient has led a very active life (squash-rackets champion at one time) and has had no trouble with his stump. He wears a Marks prothesis (wooden bucket closed with leather flaps over a tongue, solid ankle, and sponge-rubber foot.

it is worth performing (5, *24),* since it ensures a shank of more or less normal length (Figs. 39 and 40).

It is interesting to record that among Syme's earliest cases were three children *(32, 33),* ages respectively 11 years, 10 years, and 5 *months.* In all three a good result was obtained.

MALIGNANT DISEASE OF THE FOOT

Malignant disease of some part of the foot, for example malignant melanoma, is an occasional indication for Syme's amputation. Under appropriate circumstances, tumours of the tarsus, such as osteoclastoma, may be well treated by Syme's amputation. As already noted, one of Syme's outstanding successes was an amputation at the ankle joint performed for "an erectile tumour of the foot" (probably a haemangioma). In general, it may be said that any tumour of the foot which can be completely removed without sacrificing any of the principles of the amputation should be regarded as a problem suitable for treatment by Syme's amputation.

RESULTS AND CONCLUSIONS

It is difficult to discuss the results of Syme's amputation because success or failure is so much dependent upon the manner in which the operation has been performed. No matter how many Syme's stumps may be examined to ascertain the end results, the conclusions will be misleading unless the technique of the operation is known for each case. If the basic principles have been observed, and if the operation has been performed properly, the result is an assured success. If any of the fundamental principles have been disregarded, the result may be unsatisfactory, and it may not be possible to improve it. The four basic principles are simple and clear-cut: 1. to remove the damaged foot by disarticulation at the ankle joint; 2. in doing so to preserve the heel flap with its blood supply and weight-bearing qualities unimpaired; 3. to remove the malleoli and the articular cartilage on the lower end of the tibia leaving a surface of support as broad as possible; and 4. to secure

the heel flap to the ends of the tibia and fibula in the best position for weight-bearing. When these principles have been followed and the operation has been performed properly, the result almost invariably is a satisfactory end-bearing stump (Figs. 41 and 42). But the less perfect the operation the less perfect the result. If some of the principles have been imperfectly applied or some of the details of the operation neglected, the result will not be an ideal Syme's stump, though it may serve the patient's needs with reasonable satisfaction for some period of time. If the principles have been completely neglected and the operation performed without regard to the precise details of technique, the resulting stump will be unsatisfactory and beyond improvement by any subsequent operation limited to the stump.

Where, in the past, tradition has given rise to a somewhat blind but devoted adherence to Syme's perfected technique, the result has usually been a firm conviction that Syme's amputation is a good amputation. Where attempts have been made to improve upon the operation, usually in an attempt to simplify the limbmaker's problem or to provide a smaller and neater stump, the results have been indifferent or poor, and the operation has been condemned on inadequate grounds. This paper is the first since Syme's day to explore the reasons for the success of Syme's amputation in his hands and in the hands of those who followed him and for the failure of otherwise able surgeons to achieve equal success when they neglected or modified Syme's technique. The first merit which Syme claimed for his new procedure was "that the risk to life will be smaller." That indeed was the case in his day, when it spared the patient the dangerous amputation at the upper end of the tibia. Today this argument in favour of Syme's operation is no longer valid, since we now know the nature of infection and have solved the problem of its control. Though the environment of surgery has changed fundamentally from the preantiseptic era of Syme to the aseptic, bacteriostatic, and antibiotic era of today, his amputation at the ankle joint still has the other merits he claimed for it—"a more comfortable stump, more seemly and useful for support and progressive motion." When circumstances permit it to be performed, Syme's amputation provides indeed the most useful of all amputation stumps of the lower extremity.

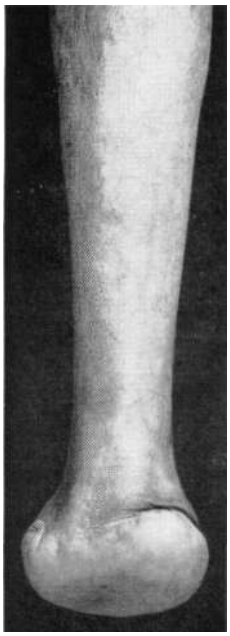


Fig. 41. A good functional Syme stump. The heel flap is large and firmly fixed to the lower end of the tibia in good position.

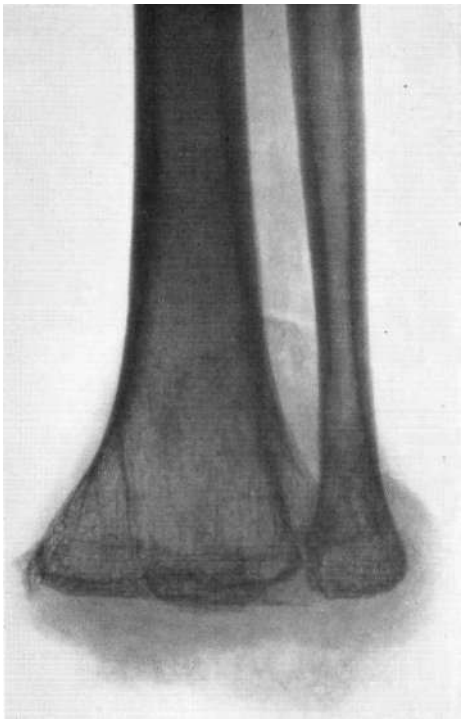


Fig. 42. Radiograph of the Syme stump shown in Figure 41. The area of support is as broad as possible.

The history of Syme's amputation during the years since Syme first performed it shows that it has been used widely throughout Europe

and North America with variable results. Syme's early cases had the good fortune to escape the complications due to sepsis, such as marred Pirogoff's early experience with the operation. Syme built on the experience he gained in his early successes and gradually perfected a technique which gave a good stump. In Syme's papers on the subject there is no record of a failure or a death, a circumstance extraordinary in view of the sepsis which to some degree complicated every surgical procedure of that day and also in view of the fact that many of his amputations were undertaken for tuberculous caries of the ankle joint or subastragalar joint. The explanation may lie in the fact that in Syme's day operations in the home and in small private hospitals were much less likely to be complicated by "hospital diseases" than were those performed in public hospitals. From 1829 to 1833, all of Syme's operations were performed in the private hospital he established in Minto House. Even after his appointment to the Chair of Clinical Surgery in the University of Edinburgh in 1833, he continued for another 15 years to act as the consulting and operating surgeon of Minto House Hospital and Dispensary, though wards in the Edinburgh Royal Infirmary were assigned to his official position. Syme was well aware that hospital diseases were in some way related to the overcrowding and filth that were universal in public hospitals of that day. The Minto Surgical Hospital, which he founded and controlled, was much less troubled with these complications because he was able there to avoid overcrowding, to ensure adequate ventilation and sanitation, and to segregate ailing patients from those in good health. In discussing compound dislocation of the astragalus, for example, he makes the following reference *(32, 36)* to this aspect of the surgery of his day:

> Compound dislocation of the astragalus with or without that curious displacement of the astragalus, which results from falling with great force on the heel, was formerly held to require amputation of the leg. The authority of Sir A. Cooper's experience encouraged attempts to preserve the limb in such cases; and in private practice both forms of injury are now frequently conducted to a successful issue, though in general through a protracted period of recovery. But it must be admitted that many lives have been lost, especially in hospitals, from trying to retain the limb. In the Royal Infirmary I find that of thirteen patients who had suffered compound dislocation of the ankle, and were not subjected to amputation, only two recovered.

When Syme assumed charge of wards in the Edinburgh Royal Infirmary, he bent all his energy toward improving sanitation by providing adequate space between beds, by better ventilation, and by more cleanliness. An interesting outcome of this activity was his insistence that the Governors establish a separate hospital for the treatment of burns. The story is well told by Simpson and Wallace *(29).* Syme's purpose was not so much to improve the treatment of burns as to remove the unfortunate burn victims, with their offensive wounds and filthy dressings, from his surgical wards to avoid contamination of his operative cases. PirogofFs experience with his first four cases of Syme's amputation, all of whom died (of scurvy, tuberculosis, and sepsis), must surely be an indication that the surgical wards of Russian hospitals provided an environment much less favourable to surgical operations than did Syme's private hospital at Minto House or his surgical wards at the Edinburgh Royal Infirmary.

It is said of Syme that he never wasted a drop of blood, never wasted a drop of ink, and never wasted a word. His publications on the subject of his amputation at the ankle joint were limited to the five papers *(30, 31, 32, 33, 35)* finally gathered together in *Contributions to the Pathology and Practice of Surgery (36)* and to his letter to the editor of *Lancet (37).* Having developed a new operation and perfected it to his satisfaction, he published the account of its value. He indicated how the complications and imperfections could be avoided and then left it to stand on its own merit. It must be said also that in Edinburgh his operation has always been held in high repute and that his technique for the procedure has been taught without change to successive generations of students. From the present survey it seems clear that when Syme's operation is condemned because of a poor stump it is almost always because of some obvious failure to follow Syme's technique. As time goes on, more and more evidence accumulates to demonstrate that Syme's operation, properly performed, will provide a good stump.

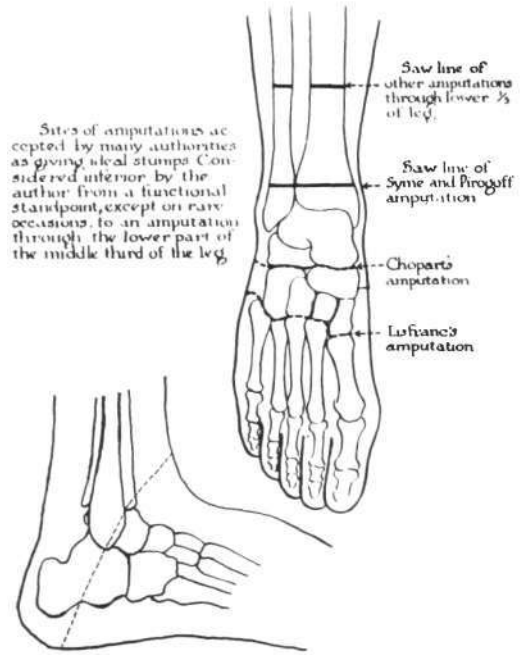


Fig. 43. Drawings from Kirk *(20)* showing misconception of the principle of Syme's amputation as late as the year 1942. The indicated level of division of the tibia and fibula is too high; description of Syme's amputation as a "supramalleolar amputation" is incorrect; the skin incision shown is that of Elmslie's modification of Syme's operation, not that used by Syme himself.

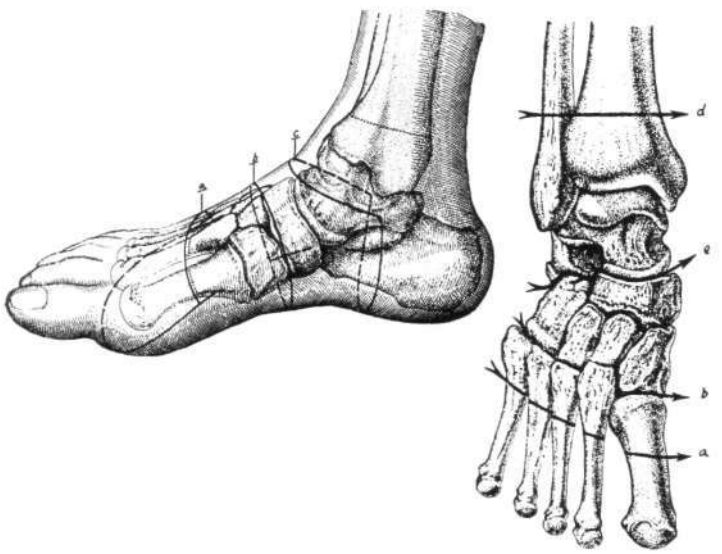


Fig. 44. Drawing of Syme's amputation showing division of tibia and fibula at a level much too high for a satisfactory stump. From Vasconcelos *(42)*.

Imperfections are almost invariably the result of failure to follow strictly the details of technique *(22)*.

It is strange that over the years there has been such imperfect appreciation of the principles of Syme's amputation. In Syme's own day, Guyon, Roux, and Pirogoff modified Syme's procedure in the hope that they might avoid certain complications. After the 1914—1918 war, Elmslie introduced his modification, which he confidently believed to be an improvement upon Syme's original technique. Even during the 1939-1945 war, and in subsequent years, the basic principles of Syme's operation were imperfectly understood. Figures 43 and 44, taken from standard texts of that era *(20, 42)*, advocate such a high transection of the tibia and fibula that the result would certainly be an imperfect stump. None of these changes in Syme's procedure has improved the results.

Such misunderstandings must be due to several factors. For one thing, Syme himself wrote about his amputation at the ankle joint in a limited way only, in a style always terse and often obscure, and he published nothing on the subject after 1846. In his publications there is only one inadequate illustration (Fig. 23). For another, in Syme's day the matter of prime importance was to remove the patient's damaged or infected foot with minimum risk to life. That accomplished, perfection of the stump and fit of the prosthesis were secondary considerations, important but not vital. When infection disappeared as a major problem, the new mastery of surgery, derived from anaesthesia and antisepsis (later asepsis), led surgeons to think that their new freedom in operating should make it possible to refine the procedure and thus to produce a more tidy, more elegant, and more useful stump. Besides this, the demands of the limbmakers led them to believe that high

transection of the tibia and fibula would ensure that the patient could more readily be fitted with a satisfactory prosthesis. Whereas in the preanaesthetic and preantiseptic days, the emphasis in operating was upon speed, dexterity, and the control of haemorrhage, in the new freedom of painless and aseptic surgery there was a widespread impulse to devise more sophisticated operations. While the functional value of Syme's amputation derived chiefly from the resulting weight-bearing properties, the stump seemed bulky, clumsy, and unsightly to the new generation of surgeons. Their success in other fields of operative procedure naturally led them to the opinion that Syme's amputation, already good, could be made still better by refining the details of the technique, and the entry into the picture of highly skilled limbfitters encouraged a belief in the necessity for certain modifications to facilitate limb-fitting.

Today, fortunately, the perfection of a new type of Syme prosthesis (page 52) has eliminated the ankle-joint problem and minimized the bulbous appearance of the perfect Syme stump. Seldom in the history of surgery has it been necessary to adhere rigidly to the technique of an operation developed and perfected in preantiseptic days. Yet such is the case with Syme's amputation. The simple technique devised by Syme to spare his patients the risks of amputation at the site of election and to give them an end-bearing stump still provides the best end-bearing stump of the lower extremity.

Finally, and in summary, the conclusions to be drawn from this examination of the history and development of Syme's operation are as follows:

1. The stump resulting from a Syme operation has great merit. It bears all the weight of the body on its end and withstands the stresses of locomotion without difficulty and for an unlimited time. It is the most satisfactory amputation of the lower extremity and should be utilized whenever circumstances permit.

2. A satisfactory Syme stump can be assured if the principles underlying the operation are understood and if the technique of the operation is followed strictly.

3. Deviation from the basic principles or from the details of the technique of the operation will impair the perfection of the stump, and imperfections thus incurred cannot be corrected by subsequent operation. Though imperfect, a Syme stump may still be useful, but sometimes it is ruined irreparably.

4. All surgeons who have occasion to deal with trauma or disease of the foot which may require amputation should be familiar with the merits of Syme's amputation and should be prepared to utilize it when the occasion arises. They must be familiar with the principles of the procedure, and they must perform the operation with meticulous adherence to the technique which has proven successful. Interestingly enough, that is the technique which Syme himself perfected.

This account of the history and development of Syme's amputation cannot end better than with Syme's own summary of the operative problem, which has been quoted earlier:

THE AMPUTATION IS EASILY EXECUTED AND PROVES IN THE HIGHEST DEGREE SATISFACTORY IF DONE IN ACCORDANCE WITH CERTAIN PRINCIPLES WHICH HAVE BEEN CAREFULLY EXPLAINED, BUT IS DIFFICULT AND DISASTROUS IF PERFORMED INCORRECTLY.

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