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Rehabilitation of the bilateral below-elbow amputee by the Krukenberg procedure

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Abstract

This paper describes the surgical technique of the Krukenberg procedure being applied in the Artificial Limb Centre, Pune, India. The results of 95 amputations on 56 patients are examined with respect to cause, age and sex distribution, and level of amputation. The benefits of this amputation to the bilateral amputee are discussed.

Introduction

The hand is one of the most important parts of the human body from both the cosmetic and the functional points of view. The hand has many functions, but perhaps its importance can be best appreciated when we think of it as a projection of the human brain. Through the use of the hand and the arm, man can exploit his brain to the fullest. Through the power of adaptation the hand has been able to assume the quality of a sense organ; in this regard it acts as a supplementary eye. In total darkness where the eyes fail, the hand gives a greater sense of security. Its highly sensitive skin provides the most important sense of touch. Since the hand performs most of the functions—ordinary or specialized—it contributes to the economic and social well-being of the individual.

Loss or impairment of its function therefore results in a great catastrophe, of even a greater magnitude if both the hands are lost (Fig. 1, top) because it results in total loss of functions. He is reduced to a state of total dependence, even for normal activities of daily living. Loss of vision in addition sometimes where it occurs in blast injuries, adds insult to the injury.

Over a number of years there has been a great improvement in the design and function of upper limb prostheses. These prostheses, though not comparable to the human hand and arm, provide a good functional substitute for them. However, no upper limb prosthesis has yet been devised which compensates for the loss of sensation and prehensile function caused by amputation of the hand. A bilateral amputee who is also blind

Fig 1. Top, bilateral through-wrist and below-elbow amputees. Bottom, Krukenberg stumps.

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wants to be able to feel, as he cannot manage a prosthesis because he cannot see.

The Krukenberg operation, a plastic procedure in which the forearm is phalangised into a radial and ulnar ray, is of inestimable value to the bilateral below-elbow amputee (Fig. 1, bottom) especially to those who are blind. The great advantage of this operation is that prehension and sense of touch are preserved, and he is spared the trouble of putting on prostheses for functional purposes.

This operation is very popular in India and is routinely performed in our centre. It is so popular that patients ask for it despite its unsightly appearance. Though the result is not cosmetic, the patients are pleased, because of the ability to feel, and also, if they desire, a prosthesis can always be worn for cosmesis. It is primarily due to its unsightly appearance that the operation is disliked by patients in the Western world.

Surgical technique

The object of this operation is to convert the fore-arm to forceps, in which the radial ray acts against the ulnar ray, with tactile sensibility. The technique followed in our centre is the standard one except for a few modifications.

The skin incisions are made in such a fashion that the radial ray is covered in its entirety with the available skin, and if needed, a small part of ulnar ray is covered with split thickness skin graft.

We make incisions keeping in mind the length of the below-elbow stump (Fig. 2). If the standard 7-8" (175-200 mm) long stump or shorter stump is available, a U-shaped incision is made starting at a point 3" (75 mm) distal to the flexor crease of the elbow passing longitudinally close to the ulna, turning around the end of the stump to a point at the same level on the dorsal surface.

In a longer stump (Fig. 3.) in the vicinity of the wrist joint or through-wrist disarticulation cases, it is always possible to cover both the rays with the available skin, by making suitable 7-shaped skin incisions. In such a case 4½" (114 mm) long longitudinal incisions on the anterior and posterior aspect close to the ulna are made starting from a point 3" (75 mm) from the flexor crease of the elbow. The ends of the two incisions are then joined by a transverse incision along the anterior, lateral and posterior aspect of the fore-

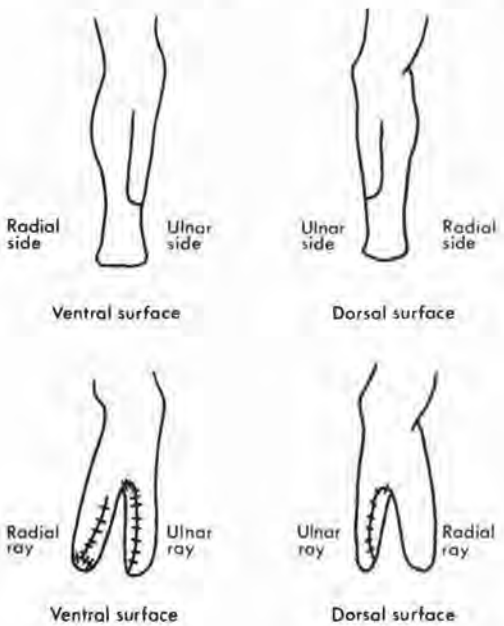

Fig 2. Incisions for the shorter stump.

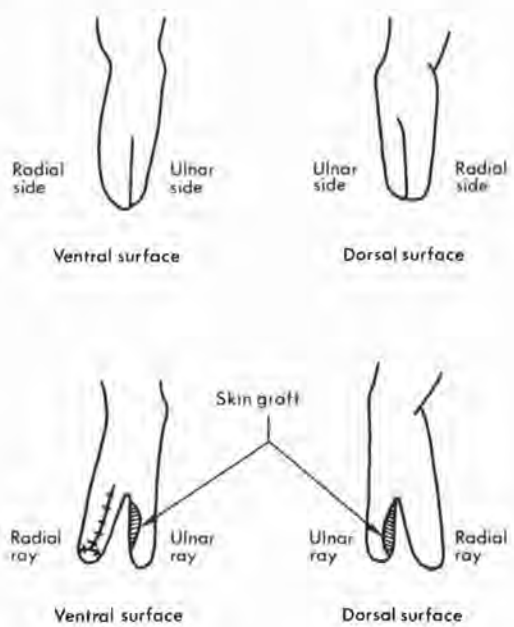

Fig 3. Incisions for the longer stump.

arm to give a 7-shaped incision. By making such an incision the skin distal to the level of the transverse incision can be utilized to cover the ulnar ray in its entire extent.

After raising the flaps the forearm is split into two parts by carefully separating the muscles and dividing the interosseous membrane. The radial half carries along with it the radial wrist flexors and extensors, the radial half of flexor digitorum sublimis and the radial half of extensor digitorum communis, brachioradialis, palmeris longus and the pronator teres, and on the ulnar side, ulnar wrist flexors and extensors, ulnar halves of flexor digitorum sublimis and extensor digitorum communis.

To reduce the bulk of the stump it is recommended by some to resect certain group of muscles. We do not advocate resection of muscles with a view to maintaining the vascularity of the stumps. Further it helps in providing adequate soft tissue cover to the stumps all around. Stumps in which too much muscle resection is carried out, are bony and therefore patients experience discomfort or even pain while holding objects.

After separating the muscles, the interosseous membrane is incised all along its ulnar attachment, so that interosseous vessels are not damaged

The radial and ulnar rays are then gently separated to achieve a separation of about 5″ (125 mm) at their tips. Thereafter both the bones are cut at a distance of 7″ (175 mm) from the flexor crease of the elbow joint. Before cutting the bones, we always raise a periosteal sleeve about ½″ (12·5 mm) long distal to the level of the bone sections. This important step helps in covering the exposed surface of the bone ends with its own periosteum and also prevents the cut end of the muscles from retracting. It is followed by stitching the cut ends of the muscles at the end of the bones, and also near the separated interosseous membrane sites, so that the rays are covered all round with muscles.

The nerves and vessels are treated in the usual manner. However, the median nerve, which is bared along its entire extent, is resected high up near the web of the rays.

Haemostasis is secured after releasing the tourniquet, and the radial stump is closed with available skin flaps. Part of the raw surface of the ulnar stump may need to be covered with a split thickness skin graft. In long below-elbow stumps or through-wrist stumps, however, the stump can always be covered in its entirety with locally available skin flaps. A drain is usually put in for 48 hours. After about three weeks, rehabilitation to develop abduction and adduction of the rays is begun.

Clinical material and results

Experience of 95 Krukenberg operations performed on 56 patients by the authors in this centre has been included in this series. The cause of injury leading to loss of hands is shown in Table 1.

Table I. Cause of amputation

Cause	Number	
Blast injury (bomb, mine or other explosives)	23	(41·1%)
Machine accidents	20	(35·7%)
Railway accidents	6	(10·7%)
Road accidents	4	(7·1%)
Electric burns	2	(3·6%)
Shell injuries	1	(1·8%)
Total	56	

Blast injury followed by machinery accidents accounted for loss of limbs in the majority of cases. The blast injuries (41·1%) which include bomb explosion, mine-blast and other explosives resulted in injuries to men whose job involved handling such dangerous explosives. Machine accidents in which the hand accidentally gets caught accounted for 35·7% of cases.

The majority of cases (39) occurred in young people between 16 and 30 years of age, since it is the young ones who are more exposed to hazardous work. The youngest patient in the series was aged 10 years and the oldest 60 years. In the series of 56 cases there was only one female patient who had sustained bilateral below-elbow amputation as a result of a railway accident. Such a great disparity in the incidence of trauma in females is obviously because they are less exposed to a hostile or dangerous environment.

Table 2 shows the level of amputations in various patients before they were subjected to Krukenberg operation.

Table 2. Level of amputation

	Number of patients
Bilateral—below-elbow	34
Bilateral—through-wrist	6
Bilateral—above-elbow and below-elbow	9
Bilateral—above-elbow and through-wrist	3
Bilateral—partially mutilated hand and through-wrist	2
Unilateral—below-elbow	2
Total	56

The various patients who underwent bilateral or unilateral Krukenberg operations are shown in Table 3. In all, 95 Krukenberg operations have been performed

Table 3. Krukenberg operations

	Number of patients	Number of operations
Bilateral Krukenberg	39	78
Unilateral Krukenberg-		
on bilateral amputees	15	15
on unilateral amputees	2	2
Totals	56	95

Seventy-eight bilateral Krukenberg operations were performed on 39 bilateral below-elbow and bilateral through-wrist cases. Fifteen unilateral Krukenberg operations were done on bilateral upper limb amputees, as they had above-elbow amputations on the contralateral side in 12 cases, and partially mutilated hands in 2 cases. In one case, though he was a bilateral below-elbow amputee, this procedure could not be carried out on one side due to a very short stump. In this series we had two unilateral below-elbow amputees on whom this procedure was done on demand, because they felt that they would be better off functionally with such a stump. Normally in a unilateral case this procedure is not essential.

The operation has been successful in all cases, and each patient has benefited immensely by it. It has been a pleasure to watch bilateral Krukenberg cases having achieved total independence not only in activities of daily living but also settled in jobs. After adequate training they were able to attend to their personal hygiene, dress, eat (Fig. 4), smoke, write (Fig. 5), cycle and attend to their jobs most satisfactorily. However, they find it too difficult to button up their shirts and are unable to perform heavy manual work. Those patients whose jobs entailed heavy manual work, were fitted with conventional working prostheses with terminal devices. The majority of the patients do not mind about their appearances. They are more concerned about the function and usefulness of these stumps rather than cosmesis as their very existence depends upon their ability to use their Krukenberg stumps. The majority of the patients have always accepted this operation willingly and take pride in the demonstration of their functional capabilities following this reconstructive procedure. However, they have all been fitted with suitable prostheses for cosmetic purposes. It has been our experience that quite a number of patients, though initially wanting such a cosmetic prosthesis, ultimately give them up altogether, either because they do

Fig 4. Eating with the Krukenberg stump.

Fig 5. Top, patients with Krukenberg stumps drinking and writing. Bottom, smoking and combing hair.

not find them so useful, have overcome their earlier shyness or are unable to buy another one.

In bilateral amputees on whom unilateral Krukenberg procedure was carried out, because the contralateral limb either had too short a below-elbow stump or had amputations above-elbow, the functional results were not so good as compared to bilateral Krukenberg cases. These patients had to depend on a prosthesis for function on the contralateral side. However, with adequate training in the use of the Krukenberg stump with a prosthesis on the opposite side, they could manage fairly well.

Discussion

The Krukenberg procedure, though not good to look at, is extremely popular in India and is routinely performed in our centre. The majority of the patients ask for it, or rather demand it to be more precise, because their very existence depends upon their ability to use these Krukenberg stumps. Its popularity is primarily due to the patient's reactions towards the plastic procedure. They find it so useful that they do not care about its appearance. The majority of such severely disabled patients with total loss of function are more concerned about regaining their lost functions rather than their appearance. However, the appearance of a bilateral below-elbow amputee with or without a prosthesis with a hook, is not a very pleasant sight either. Such patients may hide their disability by wearing cosmetic hands, but it becomes apparent when they wear hooks and other terminal devices for working purposes. Krukenberg stumps can also be hidden in a similar fashion if so desired. Therefore the correct solution to the problem in our mind is in its acceptance by the patient and the society in a fashion similar to congenitally deformed limbs. Such patients in our society are quite acceptable, and the patients themselves take pride in demonstrating their functional capabilities with such stumps.

The greatest advantage of this operation is in the retention of the tactile sensations, which no prosthesis can substitute, a factor of inestimable value in the case of the blind. Because of retention of sensation and muscle power they are able to have very effective control over the activities being performed by these stumps. They can hold objects very firmly or softly without crushing if the object is soft or fragile. They are able to lead an absolutely independent life and are spared the trouble of putting on a prosthesis, a factor of great importance to those who cannot afford a prosthesis. In fact, quite a number of patients discard their prostheses after a little while due to freedom of activities attained by the Krukenberg stumps.

Though this procedure is usually indicated for bilateral below-elbow amputees, it is sometimes applicable to a unilateral amputee. Unilateral Krukenberg operation is indicated for those who are also blind, those who cannot afford a prosthesis, and for those in whom loss of function of the dominant hand has not been taken over by the supporting hand either due to lack of interest on the part of the patient or due to disease or disability.

In children the bones should not be shortened while performing Krukenberg operation, so that distal epiphyses are retained and there is normal growth. This is possible only if at the time of initial injury a through-wrist disarticulation was performed. However, in those cases where the distal epiphyses have already been sacrificed, no further shortening of the bones should be done while performing the Krukenberg procedure.

The success of this procedure is largely dependent upon the patient's motivation and the post-operative care in training the forearm muscles in performing adduction and abduction movements of the radial ray over the ulnar ray. Normally it takes about 3–4 months from the time of operation for the patient to develop sufficient power and co-ordination to perform these movements. As time passes, the power and co-ordination of movements improves, and so does the freedom of activities.

Conclusion

In this series, results of 95 Krukenberg operations performed have been presented. The operations have been successful in all cases and the patients immensely benefited, as they could achieve complete independence from a state of total helplessness and dependence on others.

The merits of this plastic procedure outweigh the sole objection of its appearance, which can be compensated for by wearing a cosmetic prosthesis for social occasions.

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