

The Krukenberg procedure: a surgical option for the treatment of double hand amputees in Sierra Leone

F Irmay, B Merzouga, D Vettorel

Summary

Background For the past 9 years, Sierra Leone has struggled with a cruel civil war in which the civilian population has been the principal target. The International Committee of the Red Cross established a surgical mission in Netland Hospital, Freetown, and during this surgical mission, we treated crippled individuals who had had one or both hands amputated. We assessed the benefit of the Krukenberg procedure to restore manual dexterity in this group. In this operation, radius and ulna are separated and a pincer-like grasp is created.

Methods From July 15, 1998, to Sept 9, 1998, we carried out the Krukenberg procedure on a group of double and single hand amputees. The main target group was double hand amputees, however, the procedure was initially done on three single hand amputees to assess the functional result. Between the original trauma and the operation, there had been an interval of 3 months or longer in all patients. Patients were followed up for 3 months after the procedure to assess gripping strength and self-sufficiency (feeding, personal hygiene, dressing, and manual dexterity).

Findings 15 Krukenberg procedures were done on 11 patients: eight men and three women (mean age 42 years). Three had single hand amputation and eight had double hand amputation. In only two patients had sufficient time passed for the stumps to heal. Of ten patients who were followed up at 3 months, all could eat and drink by themselves. The simple dressing test was passed by all patients and 75% of the patients had recovered some dexterity.

Interpretation The Krukenberg procedure is a surgical option to achieve some manual dexterity in double hand amputees, where resources for sophisticated hand prostheses are lacking.

Lancet 2000; **356**: 1072–75

Introduction

The Republic of Sierra Leone lies on the south-west coast of Western Africa. The population is composed of 18 ethnic groups, the more numerous being the Mends and the Temps. The Creoles, descendants of freed slaves, comprise 2% of the population and live mainly in Freetown. English is the official language. Animism is predominant; 30% of the population is Muslim and 10% Christian.¹ According to a 1996 United Nations estimate,² the total population is 4 300 000, almost half of whom are less than 15 years of age. Infant mortality is 133 per 1000, global life expectancy is 39 years, and an estimated 70% of adults are illiterate. Sierra Leone is a country of low human index development, is highly in debt, and is currently benefiting from humanitarian aid on the grounds of constant insecurity and pauperisation caused by the civil war.³ During 9 years of war, deaths have exceeded 20 000 and almost 1 000 000 people have been displaced.⁴ Characteristic of this human disaster are the catastrophic infant mortality rates, unprecedented starvation, and an ever-increasing flow of refugees to the borders, and numerous exactions on civilians—with mass slaughters, mutilations, torture, and forced enrolment of children in the various fighting forces.

The International Committee of the Red Cross (ICRC) is a neutral and independent organisation entrusted by the international community with the promotion of international humanitarian law, including the four Geneva Conventions of 1949 and their two additional protocols of 1977.^{5,6} The ICRC's task is to give assistance to the civilian and military victims of war. The ICRC has operated in Sierra Leone since 1991; its activities include the distribution of food and seeds as well as farming implements; improvement of sanitary facilities and wells in villages or refugee camps allowing access to safe drinking water; visits to prisoners due to the ongoing conflict; development of a Red Cross message network for refugees and displaced persons; and offering medical aid.⁴

With the civil war, the national health system has been overburdened and the policy of “no money no cure” leaves the Sierra Leone population helpless. The survival of most depends solely on the World Food Programme, the United Nations High Commissioner for Refugees (UNHCR), ICRC, Médecin sans Frontière, Handicap International, and other humanitarian organisations.³

As is increasingly the case in many conflicts on the African continent, the contending forces have often returned to traditional weaponry. People fight with machetes alongside machine guns and grenade launchers.⁷ In early April 1998, hospitals of the Ministry of Health overflowed with war casualties leading to a complete breakdown of services that have only slowly begun to function again.⁴ The surgical hospital of the ICRC in Freetown (Netland Clinic) opened on June 26,

Department of Surgery (F Irmay MD, D Vettorel MD) and **Division of Anaesthesiology** (B Merzouga MD), **Geneva University Hospital, rue Micheli-du-Crest 24, CH-1211 Geneva 14, Switzerland**

Correspondence to: Dr F Irmay
(e-mail: François.Irmay@hcuge.ch)

1998. The objective of this mission was not to replace the existing surgical facilities but to offer, for a limited time, additional competent assistance to victims of the conflict. After 11 weeks, the ICRC team had done 334 surgical operations on 283 patients: four amputations; 121 debridements; 27 septic bone operations and sequestrectomies; 20 osteosyntheses; 20 plastic surgery procedures; 19 setting of fractures by traction or plaster; 20 delayed wound closures; three Girdlestone operations; 85 changes of wound dressing with anaesthesia (Ketalar); and 15 Krukenberg operations.

Of these 283 patients, damage was limited to the limbs and resulted from all types of penetrating trauma: machete injuries (136 [48%]), gunshot wounds (108 [38%]), landmine injuries (6 [2%]), burns (3 [1%]), and others (30 [10%]). Ears, noses, toes, fingers, and hands had been severed during the village raids. The victims took shelter in the forest and, if they survived, only had access to medical care after 2 to 3 months of travel.^{4,7}

Most leg amputees can be equipped with a prosthesis and regain a degree of self-sufficiency. The loss of one hand can be compensated by exclusive use of the other hand. A stump can support a functional prosthesis for working or else an aesthetic one.^{8,9} The concern for amputees of both hands, however, results in the loss of touch, one of our five essential senses. It deprives the maimed of external and proprioceptive information necessary to the building of the body schema.¹⁰ This sensitive function of the hand cannot be replaced and no prosthesis can alleviate its absence.⁸ In the case of the severing of both hands, a total vacuum results and the amputee faces two major issues—both survival and contact with the surrounding world.

To quantify the number of single or double hand amputees in Sierra Leone is impossible, and no complete survey can yet be carried out. In this country, poor and devastated by civil war, amputation of both hands is a sentence to an ignominious life and often to a slow and cruel death. It is obvious that this maiming with a heavy machete, violent and excessively cruel, generates crippled individuals who are totally dependent on others for survival. They can no longer feed themselves, dress, or go to the toilet without help. They find themselves a burden to a group already struggling for survival and are in a state of utter depression.

In line with its mandate under the Geneva Conventions,^{5,6} deeming this type of mutilation a serious crime against humanity, the ICRC gave double hand amputees a priority in its surgical action in Sierra Leone. We report on a programme of reconstructive surgery using the Krukenberg procedure.

The German army surgeon, Hermann Krukenberg, developed the Krukenberg procedure for phalangising the forearm early in 1917.^{11,12} In this operation, the two bones of the forearm are separated, thus creating a pincer-like grasp that gives the patient good pinch and grip with useful sensibility. Originally the target patients were soldiers injured by antipersonnel mines who were blind and had severe double hand injuries. After the operation, some patients were able to read Braille.¹² To be considered for the Krukenberg operation patients must have a remaining forearm longer than 10 cm, measured from the tip of olecranon. The pronator teres must be outlined on the palmar surface of the forearm; this muscle has to be preserved, because it is the

most important adductor of both radius and ulnar bones.^{9,13} S-shaped skin incisions are made longitudinally on both the palmar and dorsal sides of the forearm, thus creating two musculocutaneous flaps with full-thickness skin coverage on the opposing surfaces of the pincer.^{9,14,15} Muscular resection is done where necessary but some muscles have to be left intact for bone coverage as well as to improve the strength of the grip itself. The adductor muscles that are conserved include: the pronator teres, flexor carpi radialis, and the extensor carpi ulnaris. The opening function of the pincer is provided by the brachioradialis, extensor carpi radialis longus and brevis, and by the flexor carpi ulnaris.^{9,13–15} Dissection should be minimised to prevent impaired circulation and nerve damage. The ulnar and radial bones are separated by dividing the radioulnar interosseous membrane along all its length. The reconstructive part of the procedure is done after the release of the tourniquet and after careful haemostasis. The muscles are reinserted at the tip of the stump and the sensitive skin flaps are fixed on the inside of the grip, the seizing area, thus allowing tactile sensibility.^{8,9,13–15} In most cases, the outside of the pincer has to be covered with a split skin graft.^{8,9}

If the procedure is done accurately, the risk of functional failure for this procedure is low.^{8,16,17} The operation has, however, met with little interest in the western world mainly because of psychological rejection^{13,15,16}—for the bifid forearm is ugly, even repellent, to look at. However, the pincer-like grasp can lend more efficiency than an articulated prosthesis, or else be covered by an artificial hand.^{8,16} Phalangising also differs from the use of a prosthesis because of the automatic movement. With a prosthesis, each movement must be pondered, and constant sight control is needed to make up for lack of proprioceptive sensibility.^{16,18} In less-developed countries, however, gaining a measure of self-sufficiency takes precedence over the aesthetic aspect.^{9,13,19,20}

Methods

The main target group for the reconstructive procedure were patients with double hand amputations. However, the procedure was initially done in three single hand amputated patients, to assess the functional result. For all patients, an interval of at least 3 months had passed between trauma and operation.

The operation was carried out using axillary regional block anaesthesia for the unilateral Krukenberg

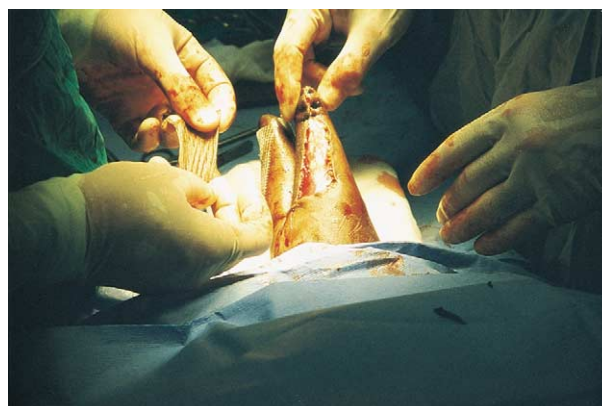


Figure 1: A bifid forearm

A split skin graft covering the outside of the pincer is the final stage in the operation.

procedure, and for bilateral cases an axillary block on one side and an intravenous lidocaine block on the other side was used (three patients) or a bilateral axillary block (one). There were no anaesthesia failures. The mean operating time was 4 h 15 min for single hand operations and 6 h 45 min for double hand procedures. All patients received penicillin for 10 days after the operation and re-educational physiotherapy was started 10 days after the operation.

If there was an insufficient skin cover for the outside of the grasping pincer the patients required a split skin graft, despite muscle loss and volume loss. The skin graft was applied at the end of the reconstructive procedure (figure 1). The follow-up time was 3 months. A longer term control could not be carried out because of the deterioration of the security situation with the war flaring up again in January, 1999. At follow-up, the following functional capacities were tested: grasping strength; ability to feed oneself; ability to manage personal hygiene; ability to dress oneself; and other manual activities.

Grasping strength was assessed by asking patients to hold against gravity an empty, half full, or full 1 L plastic bottle of water, the strength being qualified as feeble (+), medium (++), or good (+++). The patients' ability to feed themselves without help was assessed according to the ability to eat with a spoon and drink out of a cup (two activities tested). The patients' ability to clean themselves was assessed by observing the patients' ability to wash, brush their teeth, comb their hair, and, for men, shave (three or four activities tested according to sex). The patients' ability to dress themselves was assessed by asking the patient to use a zip fitted with a ring, to fasten and unfasten large buttons, to put on and take off a T-shirt, and to put on trousers or a loincloth (four activities tested).

Recovery of manual dexterity in the arms was assessed by seven tested activities: training the patient to handle small objects (cards, match boxes); perform a few household chores (brush, sweep); write; and to use heavy tools (hammer, carry a full basin).

Results

From July 15, to Sept 7, 1998, 11 patients (eight men and three women) were operated on. The mean age was 42 years (median 50 [13–67] years). All patients were right-handed. Three had lost one hand and eight had lost both hands. 15 Krukenberg procedures were done on these 11 patients. In four double hand amputees it was only possible to operate on one side because the

Patient number	Sex	Age (years)	Grasping strength	Feeding	Personal hygiene	Dressing	Manual dexterity
Single hand amputees							
1	M	36	+++	2/2	4/4	4/4	6/7
2	M	52	+++	2/2	4/4	4/4	7/7
3	M	13	+++	2/2	4/4	4/4	7/7
Double hand amputees operated on one side							
4	M	63	++	2/2	1/4	3/4	5/7
5	M	55	++	2/2	3/4	3/4	4/7
6	M	20	+++	2/2	4/4	4/4	7/7
7	M	18	+++	2/2	4/4	3/4	7/7
Double hand amputees operated on both sides							
8	F	50	++	2/2	3/3*	3/4	5/7
9	M	62	++	2/2	1/4	3/4	4/7
10	F	50	++	2/2	2/3*	2/4	4/7

*The women did not take part in the shaving test.

Summary of functional results at follow-up



Figure 2: Functional results of the Krukenberg procedure

stumps were either too short (two patients) or too septic (two). Three of the single hand amputees underwent the full Krukenberg procedure, and four double hand amputees underwent the bilateral Krukenberg procedure. All patients were manual workers (farmers, foremen) except for two students. Only two of 11 patients had healed stumps.

All patients survived the procedure. Four patients out of 11 required another operation, one of whom needed a skin graft. One patient developed a distal skin necrosis of one ray 3 weeks after the operation that required repeated debridement and then a split skin graft on healthy granulation tissue; and two patients developed distal osteitis that required sequestrectomy with shortening of the grasping jaws by about 1 cm. All operations were successful.

A follow-up functional testing control was obtained in ten patients, 3 months after the reconstructive surgery. One patient left hospital 1 month after the operation and did not attend the 3 month follow-up. During the follow-up of ten patients no amputation was needed. All patients could eat and drink by themselves. Six patients were self-sufficient in personal hygiene and four patients still needed help. The simple dressing test was managed by all the patients, but seven patients could not do the button fastening test. 75% of patients had recovered some manual dexterity (table, figure 2).

Discussion

It should be noted that nine of 11 patients presented for operation with amputation injury stumps that were still

open. We advise, however, that this kind of operation is done only when the stumps are perfectly healed because this reduces the risk of septic complications.

The patients' motivation to train their grasping stump, although difficult to assess, plays an essential part in the long rehabilitation process after the operation. Time must be allowed to gradually prepare the patient for the operation. He must be explained the limits of what he will be able to do with the phalangised stump, shown photos or videos of what it will look like, and even perhaps be given the possibility to meet another patient who has undergone the Krukenberg procedure.¹⁵ Moreover, a careful assessment of the patient's social environment, personality, and psychological equilibrium will allow doctors to better select candidates for the reconstructive surgery.¹⁶ A better knowledge about the patient will help to avoid some of the functional failures linked with the depressive state of mind of a mutilated person who has not yet overcome the severe psychological trauma.

The results indicate that for the patients who had single hand amputation, functionality improved more so than for patients with a double hand amputation. This is not surprising as the remaining hand becomes predominant with the phalangised stump only acting as a supplement.¹⁶ Nevertheless, when patients realise that they are again able to eat and drink by themselves, to dress more or less without help, to do a simple manual activity, they recover their dignity and even small results are encouraging.¹⁵ A measure of self-sufficiency enables all these patients to survive.

Contributors

François Irmay initiated the original study, supervised its design and execution, wrote the article, and operated on all the patients. Barthélémy Merzouga was responsible for all anaesthesia for the study and helped write the paper. Denise Vettorel was responsible for reference research and helped to write the paper.

Acknowledgments

We thank Chris Giannou (ICRC surgeon and co-ordinator of health activities in Geneva, Switzerland), Rose-Mary Guignard (specialist in plastic surgery in Lausanne, Switzerland), René Baumgartner (professor of orthopaedic surgery in Zurich, Switzerland), and Jan Christenson (specialist in cardiovascular surgery in Geneva, Switzerland).

Our gratitude goes to Margaret Staff, Kirsten Bennike, Grete Andreassen, Cornelia Van Wijk, Jean-Luc Metzker, and all the Netland staff.

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