THE KRUKENBERG HAND

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From Bangladesh and India

Little has been published about the Krukenberg operation, which has been regarded as primarily indicated for the blind patient with bilateral hand amputations. Of the 35 Krukenberg cineplasty operations I have performed in the last 36 years, only two have been on blind patients.

The operation provides forearm amputees with pincers which allow them to perform tasks without a prosthesis, but does not preclude the use of any type of aid. The author's operative procedure is described and the results illustrate its practical application for most patients.

Over 70 years have elapsed since Hermann von Krukenberg first described the operation that is named after him (Krukenberg 1917). World-wide reports praise the excellent results obtained (Kallio 1948; Ritsilä and Kivilaakso 1976; Nathan and Trung 1977; Powell 1978). These reports deal with the reasons for performing the operation, and the contra-indications. Some authors have recommended the operation in children as young as two years of age (Harrison and Mayou 1977; Swanson and Swanson 1980).

The Krukenberg operation is often cited following wars and military operations where bilateral injuries to the hands have resulted in amputations (Fig. 1). Few cases have been reported by any one author and large series are rare.

PATIENTS AND METHODS

The author has performed 35 Krukenberg operations during 36 years' experience. All cases except one were traumatic in origin. The patients' ages ranged from two to 40 years and they were predominantly male. Both industrial accidents and war-related injuries were involved. One child aged two had a congenital band requiring amputation. All patients were from developing countries where the cost of prosthetic devices made their use prohibitive. In most cases, the patients actually preferred the pincers to prostheses.

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The indications for the operation were:
1) a stump (in adults) over 10 cm long from the tip of the olecranon;
2) no elbow contracture, or less than 70°;
3) good psychological preparation and acceptance.

Fig. 1

Commemorative stamp showing a patient with bilateral Krukenberg stumps.

All forearm amputees who fulfilled these criteria were offered the Krukenberg procedure. In each case the stump was reduced in size using elastic bandages for several weeks prior to surgery.

Operation. The principle of the procedure is to divide the radius from the ulna to make two 'chopsticks' (*BMJ* 1978) and to attach the muscles so as to give the patient a strong grip.

A tourniquet is used, and volar and dorsal longitu-

dinal incisions are made (Fig. 2) in such a way that after separation of the stumps there will be full-thickness skin cover between the opposing surfaces of the pincers (Tubiana 1969, 1981; Nathan and Trung 1977) (Fig. 3). Care is taken to dissect as little as possible so as not to impair circulation. The volar incision is deepened through the fascia between palmaris longus and flexor carpi radialis. Flexor digitorum sublimis is split so that one half can be inserted into the radius and one half into the ulna; its radial origin is detached. Care is taken to preserve the pronator teres as it is the most important adductor of the radial stump, giving the most pinching strength. Dissection at the proximal end of the forearm is extended into the cubital fossa. The median and ulnar nerves are divided and tied distal to their branches to flexor digitorum sublimis and flexor carpi ulnaris respectively. They have no function distal to these levels.

Deep to flexor sublimis are flexor digitorum profundus and flexor pollicis longus. The entire bellies of both muscles are excised and discarded; this is an important stage in reducing the bulk of the stump. All muscles which originate below the elbow will have no function, and can be excised.

On the dorsal aspect, the area between the two heads of the extensor digitorum communis is dissected; as in the volar approach the deep layer of muscles can be excised and discarded. The distal ends of extensor communis are often adherent to the ends of the radius and ulna, and where this is the case they may remain attached to the periosteum. If they have been dissected free, they are reattached by sutures through drill holes in the bones (Mathur et al 1981). The tourniquet is then released and haemostasis is obtained.

The next step is to divide the interosseous membrane. The periosteum of the ulna is incised adjacent to the membrane and an osteotome is used to strip it from the bone. This avoids excessive bleeding from the dorsal interosseous artery. This separation is carried out as far as the proximal radio-ulnar joint and the space is opened until this joint is subluxed, allowing the radius to be abducted. The maximum opening between the ends of the radius and ulna depends on the length of the stump; for instance, with a stump of 20 cm the opening should be approximately 13 cm. After complete healing the opening will be reduced by 4 to 8 cm, so unless the maximum possible opening is obtained at operation, contracture of the pincers is likely to occur.

The ideal length of the stump is one-half to three-fifths of the forearm. Where possible this should include the insertion of pronator teres to give added gripping power. However, shorter stumps can also provide function when the patient has learned to use them. Our shortest stump was in a two-year-old child; it measured 7.5 cm from the tip of the olecranon.

Closure. The remaining muscles and tendons are attached to bone and the skin is closed without tension, taking care to rotate full-thickness skin onto the apposable surfaces. Any defects are then covered with split skin grafts. In some cases, complete primary closure can be obtained, but wherever there is doubt, grafting should be done to avoid tension. Multiple drains are left in place for 24 hours and a bulky gauze pressure dressing is applied. The stump may be mobilised in three to four days.

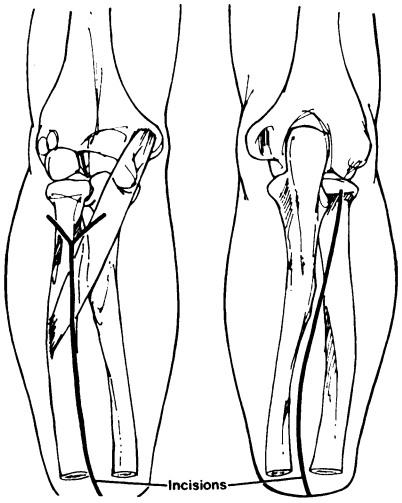

Fig. 2

Diagram to show the skin incisions in relation to the bones.

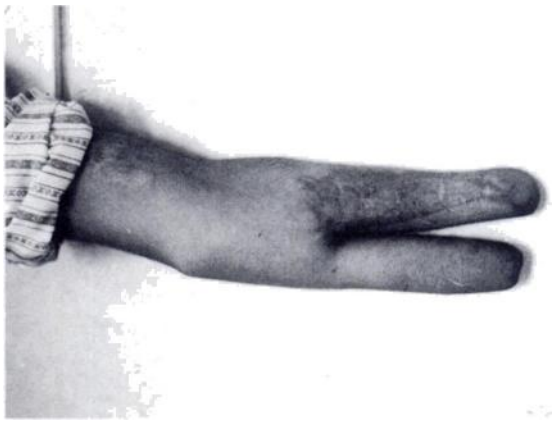

Fig. 3

Krukenberg stump showing full-thickness cover for apposing surfaces.

Complications

1) Skin slough. One patient developed skin sloughing on two-thirds of both stumps. This was caused by the use of elastic bandages postoperatively (Song 1982) and was treated by skin grafting. Sensation returned and satisfactory function was obtained.

2) Excess length of stump. Two forearm amputations at a level immediately proximal to the wrist were converted to Krukenberg stumps. These long stumps were unsightly and had poor function. After surgical shortening, the results were better.

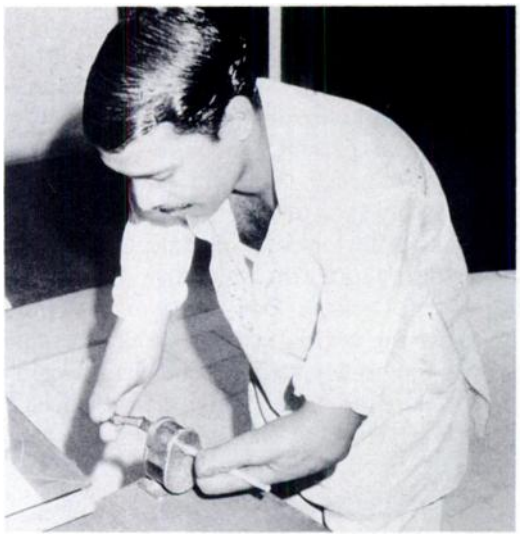

Fig. 4

Bimanual dexterity in sharpening a pencil.

3) Failure to accept appearance. One patient, a gate attendant at the hospital, had a unilateral left amputation. He refused to expose the stump for several months but gradually he began to use his pincers and at the latest follow-up, 17 years after amputation, he showed no embarrassment about their appearance.

4) Neuromas. These are rare since both median and ulnar nerves have been divided proximally. When they do occur they are excised under local anaesthesia.

5) Scarring in the axilla of the stump. This occurred in three cases and required revision and grafting which is a relatively minor procedure.

6) Fresh amputations. Two fresh amputations were converted directly to Krukenberg stumps but this proved unsatisfactory. The stumps were too bulky and skin grafting had to be delayed. We now leave a new stump to reduce in size over one or two months before performing the Krukenberg procedure.

RESULTS

We reviewed the long-term results in 10 patients with 17 Krukenberg stumps, nine of whom were sighted. We performed strength measurements on six. Grip was tested with the elbow in the extended and the flexed positions, to determine whether the pincer grip was affected by the position of the elbow. In two patients, grip was increased by 30% with the elbow flexed, but this probably resulted from forward pressure on the radius rather than true pincer grip.

The significant findings, at a mean follow-up of 15 years were:

1) all had a good pincer grip;

2) all bilateral patients could use their stumps bimanually (Fig. 4);

3) all but one of the 10 had a pincer grip which was equal to the thumb pinch grip of the examiner;

Fig. 5

A blind patient who is employed as a telephone operator.

4) all but one, a student, were employed and self supporting (Fig. 5).

The following observations have also been noted by others (Kallio 1948; Ritsilä and Kivilaakso 1976; Nathan and Trung 1977; Swanson and Swanson 1980):

1) the procedure does not prevent the use of conventional prostheses – we provided cosmetic and functional prostheses where possible;

2) No patients required reamputation at, or above, the elbow;

3) All the Krukenberg pincers functioned. The length of time to obtain good function depended on the side of dominance, whether the amputation was unilateral or bilateral, the motivation and the time required to overcome psychological rejection (this was rare).

All patients developed a good sense of touch with stereognosis which allowed them to function in the dark.

Illustrative case histories

Case 1. A 14-year-old boy lost both hands when he grasped a live electric wire. The left stump was 15 cm from the olecranon, and the right 12 cm. Krukenberg's operation was performed on the left arm at nine months and on the right after 11 months. The patient rapidly developed the use of both stumps and became a hospital orderly. Seven years later while learning brace and limb making, he started to develop hypo-aesthesia and anaesthesia in his stumps. He discontinued using a hammer and other tools immediately; sensation rapidly returned. Eighteen years after surgery he was self supporting by driving a pedicab.

Case 2. A 21-year-old guerrilla fighter was crawling through a mine-field when an antipersonnel mine exploded. This blinded him and blew off both his hands. Bilateral Krukenberg cineplasties were carried out six months after injury and three weeks apart.

The patient's personality changed dramatically when he found that he could feed himself. Some time later he had corneal transplants and recovered full vision, becoming an orderly in a hospital. At follow-up 19 years on, the patient was married with children and was employed as a security officer. He is able to fire a rifle.

Table I. Muscles acting on the Krukenberg amputation stump

Pincer function	Bone	Muscle (reattached where necessary)
Opening (abduction)	Radius	Brachioradialis
		Extensor carpi radialis longus and brevis
		Radial half of extensor digitorum communis
		Biceps
	Ulna	Extensor carpi ulnaris
		Ulnar half of extensor digitorum communis
		Triceps
Closing (adduction)	Radius	Pronator teres
		Supinator
		Flexor carpi radialis
		Radial half of flexor digitorum sublimis
		Palmaris longus
	Ulna	Flexor carpi ulnaris
		Ulnar half of flexor digitorum sublimis
		Brachialis
		Anconeus

DISCUSSION

Pincer grip is obtained by apposing the radius to the fixed ulna. Kallio (1948) measured the grasping power of 23 cases, which ranged from 3 to 10 kg. In the six patients we measured, grip varied from 3 to 9 kg. Early in our series, simple muscle stimulation was used during operation to determine which muscles operate the pincers. Our findings confirmed the reports of others (Table I; Zanoli 1957; Swanson 1964; Wilson 1976).

Advantages. The main advantage of the pincers is their versatility. The tactile sense enables the patient to perform daily tasks independently.

The procedure does not preclude the use of a cosmetic or a functional prosthesis. The latter can be operated by the two pincers; a cosmetic glove and a long sleeved shirt improves the overall appearance. The patient can control the prosthesis directly and have a very delicate sense of touch (Moberg 1975).

Without a prosthesis the patient soon realises the great advantage of his Krukenberg fingers using his prosthesis only when cosmesis is important. None of our patients elected to use the conventional hook in preference to the pincers.

We designed special handles for implements, especially for farmers, so that they could be easily grasped, and the patients themselves have also made their own modifications. In many parts of the world, amputees have neither the funds for, nor access to, functional prostheses of any kind. The Krukenberg procedure offers the patient a permanent workable alternative.

We believe that in developed countries the Krukenberg stump offers the patient a permanent hand which he may use at any time; one which he can fall back upon, when his mechanical prosthesis is not available or out of order. It is also possible that modern myoelectric prostheses could also be adapted to use with the Krukenberg stump (Heger, Millstein and Hunter 1985; Dalsy et al 1989).

The Krukenberg procedure is contraindicated where the patient is mentally unstable or has not been able to accept the procedure after adequate psychological preparation. We use photographs and other visual aids to help prepare the patient; a full explanation of the advantages is essential. We find that young children adapt more easily than adults. The physical contraindications include a flexion contracture of the elbow of over 70°, and a stump shorter than 10 cm.

Conclusion. We believe that no available prosthesis compares with the flexibility of the Krukenberg pincers, especially in day-to-day activities and light work. In the past, the standard indication in the adult has been a blind patient with bilateral hand amputations. We think this is too restrictive.

Correct technique, including the excision of redundant muscles and the correction of malunion by routine procedures, can produce pincer hands which are impressively efficient and a source of great satisfaction to the patient.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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