ULTIMATE ANATOMICAL MODIFICATIONS IN AMPUTATION STUMPS

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ULTIMATE ANATOMICAL MODIFICATIONS IN AMPUTATION STUMPS

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INTRODUCTION

These notes upon the dissection of fourteen amputation stumps were made with the desire to identify precisely the changes undergone by the soft tissues in the stump and the relation of these changes to those produced in the bones. They bring to a conclusion the series of studies reported in References 1, 2, and 8. Our material is recorded in Table I; the protocols are recorded in the laboratory but omitted here for the sake of brevity.

TABLE I

Dissected Amputations (Human)

<table>
<thead>
<tr>
<th>Site</th>
<th>Number</th>
<th>Specimen No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Arm</td>
<td>4</td>
<td>730, R; 1531, R;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1436, R, L.</td>
</tr>
<tr>
<td>Thigh</td>
<td>4</td>
<td>1519, L; 1332, L;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1686, R; 1991, R.</td>
</tr>
<tr>
<td>Leg</td>
<td>5</td>
<td>1800, R; 1471, L;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1995, L; 1697, R, L.</td>
</tr>
<tr>
<td>Foot</td>
<td>1</td>
<td>1471, R.</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Dissected Amputations (Rats)

<table>
<thead>
<tr>
<th>Site</th>
<th>Number</th>
<th>Specimen No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fore limb</td>
<td>4</td>
<td>495, R, L; 436, R, L.</td>
</tr>
</tbody>
</table>

CHANGES IN MUSCLE

The most striking single fact illustrated by the muscles of these fourteen stumps is their persistence as well nourished functional units, except where local trauma has resulted in their destruction or fibrous transformation. The atrophy of muscles in amputated limbs is strikingly different from that seen in cases of infantile paralysis, leprosy, and brawny oedema, which we have had the opportunity to dissect. In these disorders the muscular tissue is pale and bleeds very little on section. It is largely transformed into fibrous tissue with an increased amount of intermingled...
fat, the result probably of primary changes in the vascular supply. In spastic palsy, on the other hand, the atrophy is even less in amount than in surgical amputations and, as in the latter, there is slight if any vascular change.

In amputations through the lower limb or through the elbow, atrophy is not a marked feature. In our amputations above the elbow there was considerable diversity in extent of atrophy, for which the cause is not evident. Some show little or no atrophy; in others the atrophy is accompanied by a glazed and reddened skin, associated during life with angioneurotic signs—such as sensations of cold and even ulceration.

The neuralgic pain in amputations below the knee has been ascribed to vigorous growth of the fibular remnant, and this indeed may occur. Our dissections, however, show that the fibular head slips downward from its mooring on the tibia and thus projects the fibular shaft into the subcutaneous tissue of the stump. This does not occur if an osteophyte locks the free fibular end to the tibial fragment.

**APPEARANCE OF THE BLOOD VESSELS**

The commonly accepted statement that blood vessels, when ligated, become obliterated and converted into fibrous cords on healing from the point of ligation to their first large proximal branch, was not confirmed in our dissections. The main arteries and veins, as well as their larger branches, through which the operative trauma had extended, were found to be patent and apparently unreduced in caliber almost to their very end, when they rapidly dwindled in size and terminated in the general scar. Indeed, the larger veins in some stumps were found to be dilated and tortuous near their termination.

**FALSE NEUROMATA**

A statement by Leriche and Policard "that disturbances of bone regeneration are more marked after section of the median, ulnar, and internal popliteal than after section of the radial or external popliteal nerves (the former being carriers of sympathetic fibers, the latter not)" further increased our interest in the dissection of available amputations. It would have been significant, for example, if we had found the distribution of neuromata more common on one of these nerve groups than on the other. We have no objective evidence from our dissected specimens of a predisposition to form neuromata in any single nerve trunk or nerve group sectioned at operation.

Serial sections of false neuromata from our human amputations, for the most part, confirmed the findings of Huber and Lewis. Our sections and gross tumors, however, demonstrate that some neuromata are in part formed by a looping or coiling up of the nerve trunks. Neuromata on the sciatic nerve, to which the work of Huber and Lewis was confined, showed this tendency to a less degree, in our series, than did neuromata on some of the other nerves.
THE RELATION OF BONE ATROPHY TO FALSE NEUROMATA, OSTEOPHYTES, AND PROSTHESSES

In our three amputations of the upper arm, No. 1531, No. 1456, and No. 730, there were neurofibromata on all the nerve trunks severed at operation. In No. 1456 and No. 730, clavicle and scapula alike were not only atrophic but small in dimensions, whereas the atrophy in No. 1531 was negligible (See Table II). It would seem, therefore, that changes manifest in the bones of upper-extremity amputations do not necessarily accompany the development of neuromata.

### TABLE II
MEASUREMENT OF ATROPHY IN AMPUTATIONS THROUGH UPPER ARM

<table>
<thead>
<tr>
<th>No.</th>
<th>Scapula</th>
<th>Clavicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight</td>
<td>Length</td>
</tr>
<tr>
<td></td>
<td>Sound</td>
<td>Amp.</td>
</tr>
<tr>
<td>1531</td>
<td>90</td>
<td>106</td>
</tr>
<tr>
<td>730</td>
<td>63</td>
<td>31</td>
</tr>
<tr>
<td>1456*</td>
<td>54</td>
<td>40</td>
</tr>
</tbody>
</table>

* Both arms amputated. Measurements under Amp. are those of the side amputated at higher level.

Again we were unable to confirm a relationship between neuromata and bone changes in amputations of the lower extremity. In No. 1519, for example, where no neuromata were present, and in No. 1995, where three of moderate size occurred, the bone changes were slight. In No. 1800 and No. 1991 small neuromata coexisted with quite marked bone changes. In No. 1686 there was a large neuroma on the sciatic nerve, but none on the femoral or obturator nerves. This specimen showed a rather marked degree of atrophy evident, both in the roentgenograms of upper femur and innominate and in a weight loss, amounting in the innominate to ten per cent. of the sound bone (Table III).

### TABLE III
MEASUREMENT OF ATROPHY IN AMPUTATIONS OF LOWER LIMB

<table>
<thead>
<tr>
<th>No.</th>
<th>Amputation of</th>
<th>Weight of Femur</th>
<th>Weight of Os Innominatum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sound</td>
<td>Amp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>Amp.</td>
</tr>
<tr>
<td>1519</td>
<td>Left thigh</td>
<td>231</td>
<td>227</td>
</tr>
<tr>
<td>1995</td>
<td>Left leg</td>
<td>499</td>
<td>428</td>
</tr>
<tr>
<td>1800</td>
<td>Right leg</td>
<td>369</td>
<td>260</td>
</tr>
<tr>
<td>1991</td>
<td>Left thigh</td>
<td>185</td>
<td>157.5</td>
</tr>
<tr>
<td>1332</td>
<td>Left thigh</td>
<td>210</td>
<td>177</td>
</tr>
<tr>
<td>1686</td>
<td>Right thigh</td>
<td>245</td>
<td>221</td>
</tr>
<tr>
<td>1471</td>
<td>Left thigh, Right foot</td>
<td>470</td>
<td>357</td>
</tr>
<tr>
<td>1697</td>
<td>Both legs (Right higher)</td>
<td>468</td>
<td>459</td>
</tr>
</tbody>
</table>
ANATOMICAL MODIFICATIONS IN AMPUTATION STUMPS

Osteophytes or bone spurs are at times so large or so placed as to interfere with the wearing of an artificial limb and proper functioning of the stump, but our specimens give no conclusive evidence of their necessary association with bone atrophy. In No. 1991 and No. 1332 which had large osteophytes and in No. 1686 and No. 1471 where osteophytic production was slight, the atrophy, as shown by loss in bone weight, was quite marked. No. 1550 presented a marked contrast to the above specimens. This was an amputation through the left thigh of a white man, aged forty-nine years. A very large osteophyte curved proximally from the distal end of the severed femur just medial to the linea aspera. The bones themselves had not the usual atrophic appearance characteristic of amputation stumps and, though atrophy was evident in the roentgenogram, it was very slight. The innominate bone on the side of the amputation was indeed eighteen per cent. heavier than that on the sound side.

If disuse plays as important a part in the atrophy of a stump as is generally supposed, an expression of the effects of wearing prostheses in lower-extremity amputations might be anticipated. But there are no characteristic changes in the roentgenograms of our four leg amputations, which show definite evidence of artificial legs having been worn to within a short time of death, to lend support to a disuse theory. The difference in bone texture, as illustrated in roentgenograms, was just as apparent as in amputation stumps where no prostheses had been worn. Hence it seems probable that a prosthesis has no real influence upon the degree of disuse atrophy.

In No. 1697 where both legs had been amputated below the knee, the right some two and one-half centimeters higher than the left, there was a slight though definite increase in atrophy of the right innominate bone.

Differences in weight, although not as dependable as roentgenograms in determining slight degrees of atrophy because of the normal variability of bone weight on the two sides, confirm in general the findings in the roentgenograms. In No. 1697 the right femur weighed two per cent. less than the left; the innominate, three per cent. less. In No. 1800, an amputation just below the right knee in a white man, aged sixty-one years, the difference, though extreme in the femur, amounting to twenty-nine per cent. of the sound side, reached but three-tenths per cent. in the innominate bone. In No. 1995, an amputation through the upper third of the left leg below the knee in a white man, aged sixty-seven years, the left femur, though practically one centimeter longer than the right, weighed fifteen per cent. less. In the innominate bone the loss in weight was three and three-tenths per cent. of the sound side.

Our dissections and roentgenograms give us no reason to believe that there is any relationship whatsoever between false neuromata of osteophytes and atrophy or modification in dimensions of the bones in amputation stumps.
EPIPHYSEAL UNION IN AMPUTATION STUMPS

It is exceedingly difficult to obtain evidence on epiphyseal union of bones in stumps but, having followed one of our clinical cases for eight years, we have, we believe, suggestive information upon the course of events in young people.

E. Sc. is a white boy who, at the age of twelve years, following an automobile accident, suffered amputation through the lower third of the left humerus. Owing to the formation of a conical stump, the humerus was reamputated at about its middle three years later. A roentgenogram taken three years and six months after the original amputation shows a good, rounded, soft stump with a capped medullary cavity, marked gracility of humeral-shaft remainder, slightly less well marked differentiation of features of upper humeral extremity, gracility of clavicle, but no obvious change in scapula. Subsequent roentgenograms, taken five years and five months after the original amputation, show the upper humeral epiphysis and also the epiphysis forming the outer end of the acromion completely united on the amputated side alone. These unions should not occur until between the nineteenth and twentieth birthdays. Curiously enough the epiphysis which forms the coracoid angle is but partially united as on the sound side. A small center of ossification has appeared at the outer end of the left clavicle on the amputated side. This should not be present until between the nineteenth and twentieth birthdays. The ununited epiphyses and the unossified epiphysis at the outer end of the clavicle in the right shoulder are entirely in accordance with the patient’s age and clearly demonstrate the precocious epiphyseal maturity on the amputated side. The difference in date of epiphyseal union on the two sides is not accidental, for in our study of several hundred adolescents in this laboratory we have never seen it. As an evidence of early cessation of growth of the amputated limb it may, in part, explain the difference in dimensions of scapula and clavicle after amputation above the elbow. Even if we admit this contention, the retarded growth or premature arrest of growth on the side of amputation cannot wholly explain the extreme difference in dimensions and weight of our No. 730 and No. 1456. No explanation, other than actual postamputation atrophy, will suffice to explain the tremendous difference in size between the right and left scapulae and clavicles of these specimens. We are, however, still completely at a loss to account for the finding that pronounced atrophy occurs only after amputation above the elbow of the upper extremity and not at all in the lower limb.

DISSECTION OF EXPERIMENTAL AMPUTATIONS

Through the courtesy of Dr. Harold Colson of Flagstaff, Arizona, and Dr. H. H. Donaldson of the Wistar Institute, we have obtained the bodies of nine rats in which Dr. Colson had amputated the humeri through the middle of the shaft between the fifth and the twelfth days after birth.
ANATOMICAL MODIFICATIONS IN AMPUTATION STUMPS

These rats were sacrificed at different dates from 30 to 265 days after birth. In none of these rats was the epiphysis for the upper end of the humerus united. One would hardly expect union of this epiphysis before 265 days, especially since rats of the Wistar Colony tend to show delayed union. There was also no union in the epiphyses of the vertebral border or lower angle of the scapulae. All the rats were, therefore, killed before they attained skeletal maturity.

The humeral remnant shows varying degrees of gracility and, in some examples, a small osteophyte arising from the amputated stump. There is no indication of marked osteoporosis in humerus or scapula on roentgenographic examination and neither scapulae nor clavicles show the slightest sign of reduction in dimensions or of failure to develop adequately.

We have dissected the amputation stumps on rats 436 and 495 with the following results:

- **Rat 436—Right:** flat false neuroma on ulnar nerve only.
  - **Left:** moderate-siz ed neuroma on ulnar nerve, small neuroma on median nerve. No other neuromata.

- **Rat 495—Right:** no neuromata.
  - **Left:** moderate-siz ed neuroma on ulnar nerve only.

All humeral remainders in the nine rats show gracility of shaft.

The presence of neuromata upon nerves in the rats dissected indicates that there would be neuromata in the other animals, the bodies of which were macerated before we received them. The positive evidence obtained from rats 436 and 495 supports our belief that neuromata are not related to the degree of bone atrophy. However, it is not at all certain that the postoperative findings on amputations in forelimbs of rats can be transferred to a study of amputations in man. In the absence of real atrophy and in tendency to form osteophytes, the rat amputations resemble amputations of the lower extremity in man, not of the arm above the elbow. It is quite conceivable that emancipation of the forelimb in man and other primates from a weight-bearing function involves a profound difference between primate and quadrupedal function of the anterior limb. It does not appear that the rat or any other quadrupedal mammal is a suitable animal for experimental purposes in the effort to analyze the causation of postoperative phenomena in human amputations.

**GENERAL CONCLUSIONS**

1. Postoperative atrophy is seen in muscles as well as in bones. It is subject to considerable variation and is accompanied by angioneurotic symptoms of varying degree.

2. Atrophy in amputations of the lower extremity (and forearm) (See References 1 and 2) is limited in extent and in time. In amputations above the elbow it may be very pronounced indeed, and accompanied by trophic changes in the skin.

3. The atrophy of amputation is more marked than that in spastic palsy, but differs radically from that found in infantile paralysis, leprosy,
and brawny oedema because, except in the area of local trauma, the muscle of amputated stumps is never transformed into fibrous tissue.

4. The larger blood vessels retain practically their normal caliber to within a short distance of their termination, when they dwindle rapidly in size and end in the general scar.

5. A special tendency to the development of neuromata on all the nerve trunks severed at operation in amputations above the elbow is evident in our dissections. The tendency is less evident in posterior tibial and sciatic nerves and rarely present in femoral and obturator nerves of lower-extremity amputations.

6. There is no evidence in these dissections to warrant the assumption that false-neuroma formation is in any way related to the degree of bone atrophy.

7. The characteristic atrophy evidenced by loss of weight and osteoporosis identifiable on roentgenograms is present whether or not a prosthesis is worn.

8. Osteophytic production, less marked in amputations of the upper extremity than in those of the lower, has no direct relationship to the degree of bone atrophy.

9. Amputation, at least in the upper arm, may hasten the date of epiphyseal union and thus apparently arrest bone growth.

10. Experimental amputation of the upper arm in rats results in phenomena resembling the postoperative changes in amputations of the lower limb in man and not those in amputations of the upper arm.

11. The rat, being a quadrupedal mammal, is not a suitable animal for a study of postamputation changes as found in man.

REFERENCES


