
Shrinkage of the Esophagus after Resection for Carcinoma

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The purpose of this study was to document and quantitate the degree of shrinkage of resection margins of the esophagus following extirpation for carcinoma. Measurements were made at operation before the esophagus was removed (*in-situ*), when the removed specimen had been stretched maximally (stretched), with the specimen lying free (contracted), and after fixation (fixed). After resection, there was substantial shrinkage of the margins, and the upper margins underwent a greater degree of shrinkage than the lower margins, with the tumor changing little in length. In the contracted state before fixation, the upper and lower margins were reduced to 44% and 54% of their *in-situ* lengths, respectively; after fixation, they were 32% and 39%, respectively. Even after maximal stretching, only 73% of the upper and 89% of the lower *in-situ* resection margins were restored. The overall shrinkage for the whole specimen after fixation was 50%. It is concluded that there is considerable shrinkage of the resection margins in the esophagus from the time of operation to fixation, and this accounts for the discrepancy claimed by surgeons and pathologists regarding the length of the margins. This finding has relevance in the extrapolation of surgical resection margins from pathological specimens.

THE ESOPHAGUS, in common with the rest of the gastrointestinal tract, undergoes considerable shrinkage after resection and more so after fixation. Even by stretching the fresh specimen, the original *in-situ* length cannot be restored. This has practical implications in the assessment of the extent of resection margins when the operation has been performed for malignancy. Invariably, the *in-situ* margin, as estimated by the surgeon, is greater than the specimen margin, as measured by the pathologist. In contrast to the resection margins, the tumor itself shows little shrinkage. The exact extent of shrinkage of the apparently normal esophagus adjoining the tumor has not been previously documented.

The purpose of this study is to quantitate the shrinkage of the various parts of the esophagus after a transthoracic

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resection has been performed for carcinoma. By taking intraoperative *in-situ* measurements and then comparing these with the freshly resected and the fixed specimen measurements, the amount of shrinkage in the resection margins and tumor-bearing segment of the esophagus was calculated.

Methods

Patients with resectable carcinoma of the thoracic esophagus treated in the Department of Surgery, University of Hong Kong at the Queen Mary Hospital, underwent a Lewis-Tanner operation, using an abdominal and right thoracotomy approach.^{1,2} With the patient in the supine position, the stomach was prepared through an upper midline abdominal incision. The patient was then turned and the right chest opened in the fifth intercostal space and the whole esophagus mobilized.

Measurements were then taken. Because of the curvature of the *in-situ* esophagus and the limited space in the thoracic cavity, a sterile tape was used and the various lengths marked on it for measurement against a ruler. The upper level of esophageal resection was decided on and a Satinsky clamp applied. The tape was then placed along the esophagus from the clamp to the upper border of the tumor. The upper and lower borders of the tumor were determined by palpation and marked on the tape with artery forceps. The lower resection margin was similarly marked out, and the tape with the attached forceps measured against a ruler. The esophagus was then removed and reconstruction accomplished by performing an esophagogastric anastomosis in the apex of the right pleural cavity.

The contracted fresh specimen was opened along the border in such a way as to avoid, if possible, cutting

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TABLE 1. Lengths of Upper and Lower Margins, Tumor, and Whole Specimen (in cm) of the In-situ, Stretched, Contracted, and Fixed Specimen

	(N)	Upper Margin	Tumor	Lower Margin	Whole Specimen
<i>In-situ</i>	55	8.8 ± 3.5	6.3 ± 2.5	8.1 ± 3.2	23.2 ± 2.5
Stretched	43	6.4 ± 3.9	6.4 ± 2.4	7.1 ± 3.8	19.9 ± 2.8
Contracted	55	3.8 ± 1.8	5.6 ± 1.9	4.3 ± 1.8	13.7 ± 2.3
Fixed	12	2.9 ± 1.4	5.5 ± 2.7	3.5 ± 1.4	11.8 ± 1.9

through the tumor and laid out flat. As there was greater shrinkage of the mucosa over the muscularis propria at the cut edges, the ends of the mucosa were taken as the reference points for measurement. The tumor length included the visible and palpable tumor in the opened specimen. Thus, if there was intramural spread, the palpable edge beyond the visible tumor was taken as the tumor margin. In this way, as close a correspondence as possible between the palpable external *in-situ* length and internal contracted length might be obtained. The length of the whole resected esophagus and the length of the three segments, *i.e.*, from upper resected edge to upper border of tumor, the tumor-bearing segment, and from the lower border of the tumor to the lower resected edge, were measured. There were 55 sets of such measurements.

In 43 of the 55 fresh specimens, the esophagus was stretched maximally and held by pins on a cork board. Measurements of the three parts and the whole length were taken.

In 12 of the 55 fresh specimens, after various measurements were taken in the fresh state, they were fixed in 10% buffered formal saline and similar measurements taken after complete fixation, at least 48 hours later. The reason for not immediately fixing all specimens was that special pathological studies were being conducted.

Using the *in-situ* measurements as reference, the proportion of shrinkage for each specimen for the three parts and for the whole specimen in the other states were calculated. The means and standard deviations of the proportion of shrinkage for each group was derived from the proportions for individual specimens and not from the means of the absolute measurements.

TABLE 2. Proportion of Shrinkage of the Stretched, Contracted, and Fixed Specimen for the Upper and Lower Margins, Tumor, and Whole Specimen, Compared with the In-situ Length

	(N)	Upper margin	Tumor	Lower Margin	Whole Specimen
<i>In-situ</i>	55	1	1	1	1
Stretched	43	0.73 ± 0.16	1.04 ± 0.14	0.89 ± 0.24	0.86 ± 0.07
Contracted	55	0.44 ± 0.10	0.92 ± 0.15	0.54 ± 0.18	0.60 ± 0.08
Fixed	12	0.32 ± 0.12	0.90 ± 0.10	0.39 ± 0.08	0.50 ± 0.07

Results

The means and standard deviations of the absolute measurements of the upper and lower margins, tumor length, and the whole length of the esophagus for the four states of the specimen, *i.e.*, *in-situ*, stretched, contracted, and fixed, are shown in Table 1, and their respective proportions of shrinkage shown in Table 2. There was, as expected from the method of calculation employed, a close correspondence between the two sets of figures in Tables 1 and 2, and smaller standard deviations for the proportions.

The appearances of one specimen in the stretched, contracted, and fixed states are shown in Figure 1, with the *in-situ* state, as measured at operation, drawn in for comparison.

There was a relatively greater degree of shrinkage of the upper margin as compared with the lower one. Thus, although the *in-situ* lengths were longer for the upper margin than the lower margin, the stretched, contracted, and fixed specimens were shorter than the corresponding figures for the lower margins (Table 1). This difference is more clearly represented in Table 2 where the proportion of shrinkage in the upper margin is greater in all three states compared with the lower margin.

The whole *in-situ* length of the resected esophagus of 23.2 cm represents a near-total removal of the estimated 25 cm of the entire esophagus. The average length of tumor was 6.3 cm and the average resection margins were over 8 cm at both ends. The standard deviations for the resection margins were wide because the individual margins depended on the exact size and location of the tumor, which may be from the upper, middle, or lower thirds. Similarly, the standard deviation for the tumor length represented the variation of the size of tumor resected. In contrast, because the operation is standardized to remove the whole thoracic esophagus, the standard deviation for the whole esophageal length removed was small.

When the resected specimen was opened and laid free, there was a shrinkage of the upper and lower margins to 44% and 54%, respectively, of the *in-situ* lengths, with a slight shrinkage of the tumor by 8%. Stretching the resected specimen maximally did not result in restoration of the *in-situ* length, and there was a shortfall of 27% and 11%, respectively, for the upper and lower margins. Negligible change occurred in the tumor lengths.

Maximal shrinkage occurred after fixation. The upper and lower margins were reduced to 32% and 39% of their *in-situ* lengths, respectively, after fixation. The tumor shrinkage after fixation was only by 10%.

From the contracted to the fixed state, there was a further shrinkage of 12% and 15%, respectively, for the upper and lower margins, with virtually no change for the tumor.

Overall, the *in-situ* esophagus was reduced to half its

length when fixed, with the shrinkage occurring almost entirely in the margins.

Discussion

It is well known that the free margins of resected specimens of the gastrointestinal tract shrink immediately and substantially when removed from their *in-vivo* environment in the patient, and that further shrinkage occurs when the specimen is fixed in preservative solutions. Thus, pathologists invariably report on resection margins much shorter than what surgeons know to be the case at operation. In the light of our present study, both the pathologist and the surgeon are justified in their differing claims, and we have documented the extent of this discrepancy quantitatively.

The adequacy of resection margin is of particular importance in extirpation for carcinoma of the esophagus because of the apparent propensity of intramural spread, especially proximally. For this reason, long resection margins are recommended, and in practice this necessitates a near-total esophagectomy.

The extent of direct longitudinal invasion in carcinoma of esophagus is often found beyond the limits defined by inspection or palpation. Burgess and his associates³ found intramural spread up to 4 cm beyond the gross extent of the carcinoma in fixed specimens and emphasized the shrinkage of resected specimens. Liu and his associates found tumor at the cut margin in 11 of 79 specimens,⁴ and Scanlon and coworkers⁵ advocated against segmental resection for esophageal carcinoma because at least 36 of 79 patients in their study had tumor at the edge of the resected specimen. As the results in these studies were obtained from fixed specimens, it was not possible to extrapolate what the corresponding *in-situ* lengths would have been and thus assist the surgeon to decide on an adequate resection margin at operation. By applying the shrinkage factor for fixed specimens in our study to Burgess' study, a 4 cm spread in a fixed specimen would represent 12.5 cm ($4/0.32$) in the *in-situ* state.

The reason for the more extensive shrinkage in the upper margin than the lower margin may be the hypertrophy of the esophageal wall in response to tumor obstruction. The thickened proximal esophagus could be expected to contract more forcefully after resection and conversely could not be stretched out as easily as the more normal distal esophagus. Another possible explanation is that the upper esophagus contains some striated muscle fibers that may be more resistant to stretching than the lower esophagus whose muscularis propria are composed entirely of smooth muscles.

Our results showed that the upper and lower resection margins shrink to 32% and 39%, respectively, after fixation in formalin. Thus, only about one-third of the operative

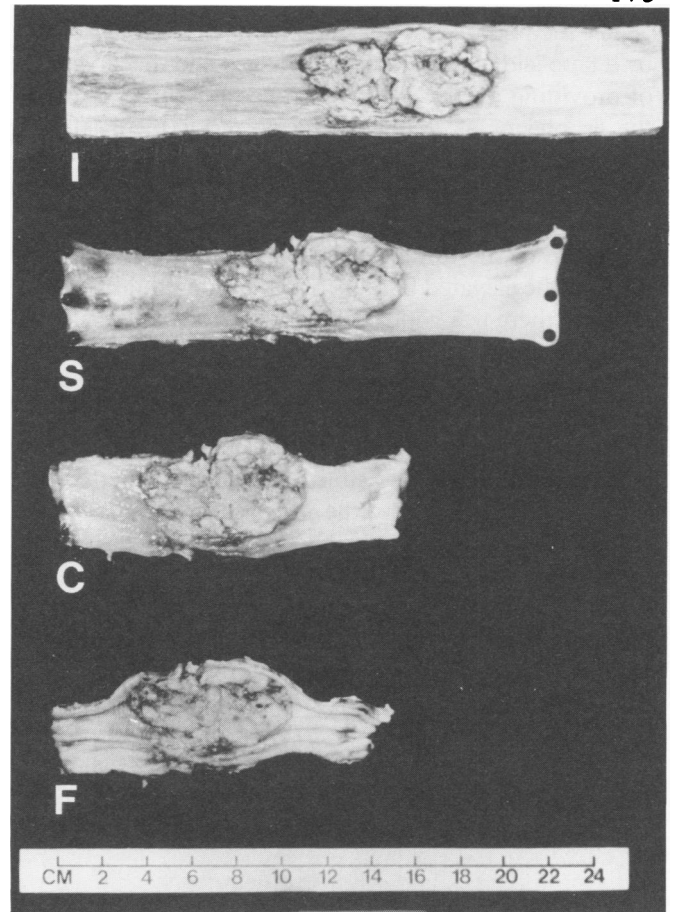


FIG. 1. Appearance of a resected specimen in the stretched (S), contracted (C), and fixed (F) states. The *in-situ* (I) appearance is reproduced by drawing for comparison. The upper margin is on the left.

resection margin remains when the pathologist studies the specimen. In contrast, there is very little shrinkage of the tumor itself (10%) when fixed. This indicates that the tumor has replaced the full esophageal musculature, which is the case in virtually all the tumors in our series. The small amount of shrinkage in the tumor may be a direct effect of the fixative or due to contraction of residual muscle fibers intermingled with tumor tissue in the outer muscularis propria.

The overall reduction in length from the whole *in-situ* specimen to the fixed specimen is 50%. The exact shrinkage in each specimen would depend on the size of the tumor, which then determines the relative proportion of the normal margins to the tumor; the longer the tumor, the less the overall reduction in length.

Even when the resected unfixed specimen is stretched to its maximal extent, it is possible to restore it only to 86% of its *in-situ* length. This would indicate that some irreversible changes in muscle fibers had already taken place immediately on removal of the specimen from the patient.

The method we employed to measure the *in-situ* lengths by a tape laid alongside the esophagus had the advantage of providing a good correspondence to the curvature of the esophagus as it lies in the posterior mediastinum. However, there was a potential source of error in using this method to measure the tumor length and therefore also the free margins. The measurements depended on palpation of the tumor edges from outside. In most instances, the elevated borders of the tumor could be easily felt, and there was good correlation between the palpable tumor size and the intraluminal size. When there was diffuse intramural infiltration or when involved lymph nodes had fused with the primary tumor, the exact extent of the tumor was more difficult to define and palpation could overestimate the visible and palpable length of the tumor as determined by the mucosal aspect. This may account for an apparent shrinkage of the tumor in some cases after resection. Inaccuracies might also have occurred in the opposite direction if the tumor had pedunculated features; in this situation, the tumor length might

be underestimated, as the tumor could be pushed in the opposite direction when the tumor edge was being palpated.

Our present data, and the results of pathological studies on the extent of intramural spread and multiplicity of tumor, could offer some rationale in deciding on what constitutes adequate resection margins for carcinoma of the esophagus.

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