ORIGINAL ARTICLES

Evaluation of local invasion by oesophageal carcinoma—a prospective study of prone computed tomography scanning

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Abstract

The aim of this study was to assess the value of prone computed tomography compared with the traditional supine position, in the assessment of invasion of adjacent mediastinal structures by oesophageal cancer. A prospective, single blind case-case comparative study of signs of local tumour invasion was conducted. Sixty nine consecutive patients undergoing computed tomography for preoperative staging of oesophageal carcinoma were studied. Computed tomography scanning of the thorax was performed in the standard supine followed by prone position; in 39 patients the computed tomography findings were correlated with the surgical findings. Four established radiological signs used to assess mediastinal invasion were scored in each case.

Based on the radiological scoring system, there was a significant down staging in the probability of aortic invasion in 12 of the 69 cases ($p<0.05$). A similar improvement in accuracy was seen in the cases undergoing surgery; of the 38 cases who did not have aortic invasion at operation, 10 cases were scored as high for aortic invasion on the supine scans compared with only three on the prone position ($p<0.05$). Prone scanning was not of significant additional value in the assessment of major airway or pericardial invasion.

Modification of the computed tomography protocol to include scanning in the prone position will improve the accuracy of the preoperative staging of patients with oesophageal malignancy and reduce the chance of overstaging disease. Especially in centres where endoscopic ultrasound is not available, our modification may reduce the chance of denying patients potentially curative operations.

(*Postgrad Med J* 2001;77:181–184)

Keywords: computed tomography; neoplasm staging; oesophageal neoplasm; local invasion

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Submitted 30 November 1999
Accepted 6 June 2000

The majority of patients with oesophageal cancer present in an advanced stage with a poor prognosis.[1] Although historically surgical resection was associated with high perioperative mortality, surgical and anaesthetic expertise in dedicated units have reduced the mortality rates to well under 10%. Overall five year survival rates have been quoted as low as 5%[2] but better results are now achieved in specialist centres. Indeed some centres are reporting five year survival rates for curative resection of both squamous and adenocarcinoma as being in the order of 20%–30%.[3] Much of this improvement has been due to better selection of patients for surgery; long term results of surgical intervention for oesophagectomy for oesophageal malignancy are stage dependent.[2]

Preoperative staging is employed to select those patients who are likely to benefit from potentially curative surgery. It is essential to exclude patients who require palliation only, so that a high risk procedure is not offered without a prospect of cure. However it is equally important that patients in whom curative resection is possible are not denied because of overstaging of disease. Although, in specialist centres, endoscopic ultrasound has been shown to improve the accuracy of local staging of oesophageal cancer,[4] computed tomography is still widely used in the assessment of oesophageal malignancy in most centres in the UK at the present time. The assessment of oesophageal tumours can be difficult due to lack of a clear contrast boundary layer between the oesophagus and neighbouring mediastinal structures such as the aorta, tracheobronchial tree, and the left atrium. For this reason, computed tomography remains inaccurate, potentially depriving a large number of curable patients of curative surgery.[5]

Previously reported studies have used computed tomography techniques with the patient lying in the supine position. Ball *et al* reported marked changes in organ position on computed tomography when the patient was scanned in the prone position.[6] Gravitational movement of the heart increases the space between the left atrium and the vertebral body, and the oesophagus moves more ventral to the aorta. The Royal College of Radiologists in a recent report has suggested that this technique may be helpful in some patients.[7] In a previous technical report from this centre, we have suggested that the computed tomography staging of oesophageal cancers can be improved by selective use of scanning in the prone position.[8] The aim of this study is to show whether scanning in the prone position, in addition to the traditional supine position, reduces the chance of false positive results for local invasion of mediastinal structures.

Methods

PATIENTS

A consecutive series of patients with oesophageal cancer referred to the unit over an 18 month period were recruited to the study. Patients with high cervical and low gastro-oesophageal tumours were excluded. Each patient underwent computed tomography of the thorax and abdomen.

COMPUTED TOMOGRAMS

One centimetre contiguous axial sections were performed throughout the chest and the upper abdomen in the supine position before and after oral contrast. After turning the patient into the prone position, 1 cm contiguous axial sections were performed extending to clear the proximal and distal margins of the tumour. Additional intravenous contrast enhanced scans were performed at the discretion of the supervising radiologist. A contemporary report was compiled and issued in the normal manner using all available information.

INTERPRETATION OF COMPUTED TOMOGRAMS

Two radiologists (SC, GJD) reviewed prone and supine scans on standard settings, blinded to their assessment of the other scan and the report issued by a third colleague (WS). In so far as was practicable, only non-enhanced scans were used. This was intended to reduce any bias of the results attributable to more contrast medium being present in one position than the other and hence confounding the results. A scoring system was devised using previously published computed tomography criteria for defining local invasion of adjacent structures. These included the angle of contact of the aortic circumference with the tumour as described by Picus *et al*,[9] effacement of the triangular fat space between oesophagus, vertebral body, and aorta,[5] and tracheobronchial and pericardial abutment or compression by oesophageal tumour.[9] A score of 2 is suggestive of invasion of the relevant structure by the oesophageal tumour on computed tomography grounds; a score of 0 indicates no evidence of invasion, and a score of 1 is indeterminate (table 1). In normal clinical practice, the diagnosis of depth of local tumour invasion would not be made using these signs alone. Instead, the radiologist relies on his experience and several other subtle signs taken in combination. The clinical signs used as markers for this study were chosen for their proven reproducibility and objectivity of scoring. They serve here then, not as absolute measures of local invasion but as a quantifiable model of how observations regarding local invasion may be affected by positional change. Scoring was performed by consensus in batches of at least 10 with referral to previously scored batches in order to ensure reasonable consistency.

Table 1 Scoring assessment of invasion of local mediastinal structures

1. Aortic invasion based on Picus' angle	
0	No contact/<45
1	45–90
2	>90
2. Aortic invasion based on triangle effacement	
0	No effacement
1	Indeterminate
2	Effacement
3. Pericardial invasion	
0	No contact
1	Absent fat plane, unless criterion 2
2	Absent fat plane at tumour level, not above or below
4. Major airway invasion	
0	No contact
1	Abutment only
2	Bulging or displacement

RESECTION

Patients were selected for surgery after comprehensive staging involving detailed assessment of patient parameters (including clinical examination, haematological and biochemical analyses, plain chest radiograph, pulmonary function tests, electrocardiography, and exercise test) and tumour related parameters (including abdominal ultrasound, endoscopy, bronchoscopy, and computed tomography of the abdomen and thorax).[10] A single surgeon (SMG) performed all resections. The operative findings of tumour invasion of adjacent mediastinal structures were scored at the time of surgery by the surgeon who was blinded to the relative findings of prone and supine computed tomography results.

ANALYSIS

Analysis was performed to assess the impact of positional change in each individual patient on a case by case basis using McNemar's test for paired variables. Radiological scores were compared with surgical findings using the χ^2 test. SPSS (Statistical Package for the Social Sciences) software was employed in the analysis.

Results

Seventy three patients were recruited to the study. Four patients were subsequently excluded for protocol violations. Thirty nine patients ultimately underwent surgical intervention.

Changes in radiological findings between prone and supine scanning position were seen in individual patients particularly with respect to diagnosis of aortic invasion (fig 1A and B). Case by case analysis confirmed significant down staging with prone computed tomography (table 2). Interestingly in three cases, aortic invasion was downstaged by performing the scan in the supine position (fig 1C).

In the group of patients who ultimately underwent surgical resection (n=39), significantly fewer patients were incorrectly described as suggestive of aortic invasion from the prone scans compared with those performed in the supine position (table 3). The only patient with aortic invasion at surgery was thought to be clear on both scans. No patient undergoing surgery had pericardial invasion. Both supine and prone scoring gave false positive suggestion of pericardial adherence in those patients undergoing surgery. Three patients undergoing surgery had evidence of major airway invasion that was correctly suggested by both prone and supine scoring. In these cases, surgical exploration was considered warranted because all other staging criteria had suggested earlier stage disease in patients fit for radical surgery. A further two patients on the supine and a single patient on the prone scan had scores

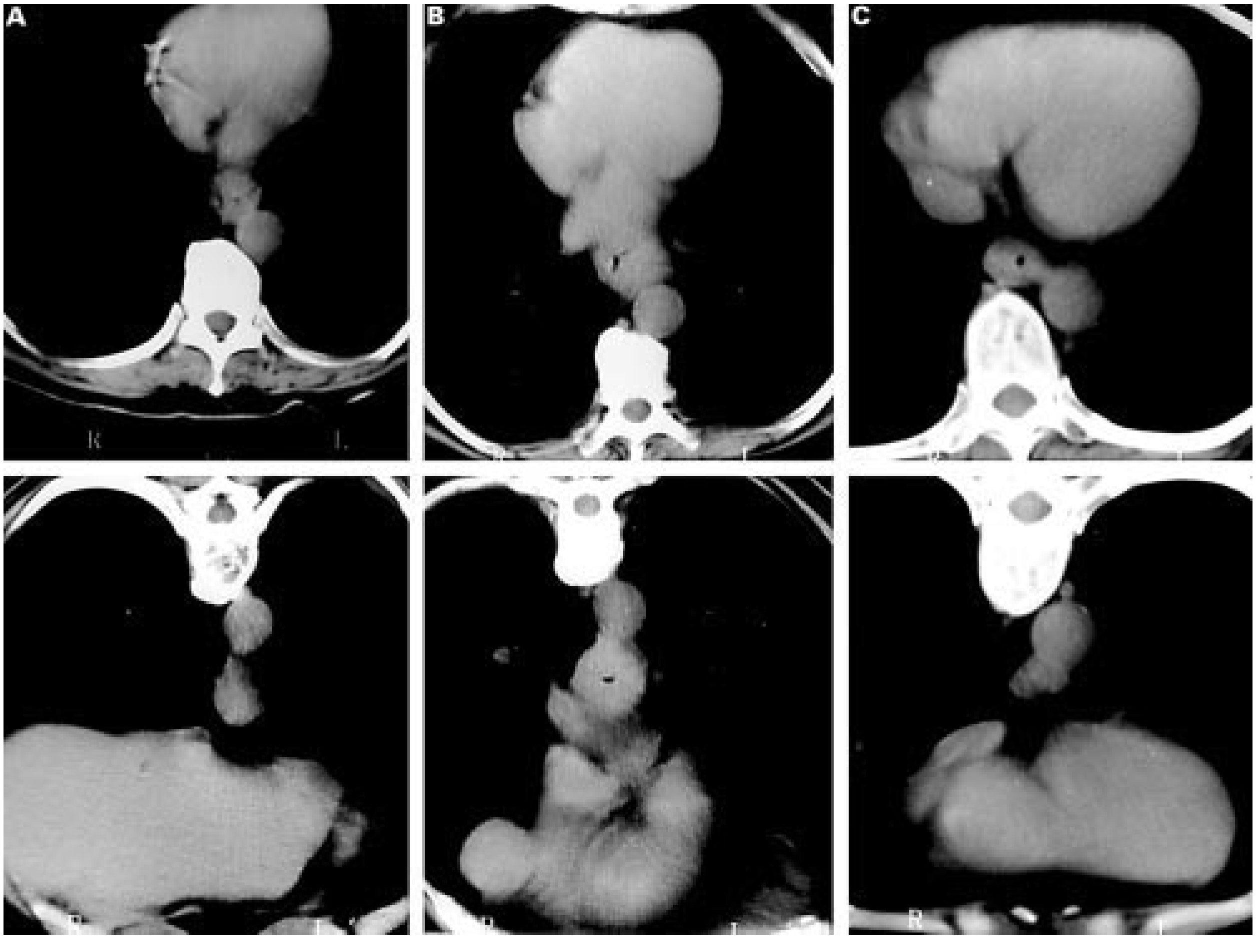

Figure 1 The illustrations consist of a pair of images from three different patients. These consist of supine and prone images at approximately the same vertebral level. Because of movement of the diaphragm between the supine and prone positions, the extent to which the diaphragm appears on the images is variable—always tending to be higher in the prone position. The aorta and oesophagus are more constantly related to the vertebrae. In all instances the position of the tumour changes with a change in position. (A) The tumour is in contact with the aorta over 45–90° in the supine position (above). The area of contact decreases in the prone position (below). (B) The tumour is in contact with the aorta over >90° in the supine position (above). The area of contact decreases in the prone position (below). (C) In this example the contact between aorta and tumour is less in the supine position (above); prone position below.

Table 2 Case by case analysis of the change in radiological opinion after prone computed tomogram result

Radiological sign	*Upstaged*	*Downstaged*	*p Value**
Aortic invasion (Picus' angle)	3†	12	<0.05
Aortic invasion (triangle effacement)	0	12	<0.001
Pericardial invasion	0	7	<0.05
Airway invasion	5	3	ns

*McNemar's test.
†Example shown in fig 1 (C).

Table 3 Computed tomography scoring for local invasion in prone and supine positions compared with surgical findings

	Positive at operation	*Negative at operation*	*False positive on supine scan*	*False positive on prone scan*	*p Value‡*
Aortic invasion	1*	38	10	3	0.04
Pericardial invasion	0	39	20	20	ns
Airways invasion	3†	36	2	1	ns

*One patient was found to have invasion of the aorta at the time of operation which had not been predicted by either prone or supine computed tomograms.
†Three patients local airways invasion correctly predicted by the radiological signs in one case in the supine position and two cases in the prone position.
‡χ^2 Test comparing false positive results of prone and supine computed tomograms.

suggesting airway invasion on computed tomography not confirmed at subsequent surgery.

Discussion

The role of computed tomography in the staging of oesophageal carcinoma remains controversial. Early reports suggested high specificity and sensitivity in assessing invasion of mediastinal structures. Reported figures for the sensitivity in detecting tracheobronchial invasion ranged between 83% and 100% with a specificity of 75%–100% with the corresponding figures for the detection of aortic invasion being 92%–100% and 83%–89%. Later studies were less encouraging with 44%–60% of tumours being incorrectly staged by computed tomography.[11] A false positive suggestion of tumour invasion of adjacent structures could potentially deprive a patient of curative surgery. If the prone scan could decrease the number of false positives, it could be a useful technique.

If an oesophageal cancer can be shown to be inoperable because of infiltration or adhesion to mediastinal structures, particularly the aorta, then postural movement between the tumour and the organ in question can reasonably taken *a priori* as an indication that there is no such impediment to surgery. This study shows that movement does occur between supine and prone positions in a proportion of patients. Thus, if a radiologist or surgeon is concerned on the basis of a supine scan that there may be aortic invasion, movement of the tumour relative to the aorta in the prone position will often occur and will increase the confidence of excluding or diagnosing invasion.

The criteria for invasion were selected for this study as they are recognised methods of assessing tumour contact with adjacent structures with good reproducibility. Comparing the findings in individual patients (case by case) shows significantly more patients converting from radiologically positive to negative scores by the findings on the prone scan. This applies when assessing aortic invasion by both Picus' angle and fat triangle effacement, and in the assessment of major airway invasion. The number of positives on the supine scan is therefore reduced by the additional use of the prone scan. The observation of three cases in which disease was upstaged by prone scanning suggests that while in isolation prone scanning is less likely to overstage disease, more accurate still is to compare both prone and supine scans. Comparing the radiological assessment with the surgical findings confirms that a negative result on computed tomography is reliable. Albeit with small numbers in each category, there was only one false negative result for aortic invasion, and none for the major airways or pericardium. The larger number of patients converting to negative by the use of the prone scan is therefore helpful in avoiding patients being denied surgery by false positive results for mediastinal invasion.

There are several important limitations of this study. There were only a small number of patients who actually were found to have mediastinal invasion at the time of surgery. In addition, patients in whom mediastinal invasion was unequivocal were not subjected to surgical evaluation. For these reasons, we cannot sensibly assess the sensitivity, specificity, or accuracy of the criteria used. The radiological signs were taken out of the context of the overall impression given by the computed tomography and other staging investigations and hence are not entirely representative of the normal clinical situation. Despite its shortcomings, the study shows that the additional use of the prone scan is useful in improving the radiological assessment of local invasion. Of the 27 patients with suspected aortic invasion on the prone scan, 13 (44%) were assessed as clearly normal on the prone scan. In practice, a proportion of these patients would have other factors disposing against surgery—for example, lymph node enlargement, metastasis, or general cardiorespiratory status. None the less a proportion of false positive results are avoided by the use of this technique. Extrapolating from our findings, and other reported results,[11] we suggest that the radiologist must be very wary of suggesting the aorta, pericardium or major airways are invaded, simply by virtue of the intimate contact with the tumour as shown on supine position computed tomography alone.

Alternative imaging strategies have been used in the assessment of local mediastinal invasion by oesophageal carcinoma. Magnetic resonance imaging has not been shown to confer any advantage over computed tomography, perhaps because the same "invasion criteria" have been used.[5] Endoscopic ultrasound is highly accurate in the assessment of local mediastinal invasion and in the assessment of mediastinal lymph node spread.[12] However, the technique is limited by the inability of current probes to cross 25% of strictures, and in the UK at least, is confined to only a few centres. Computed tomography is therefore likely to remain an important staging tool in the assessment of oesophageal carcinoma for the foreseeable future and it is important to optimise the technique.

In conclusion, this study confirms that a simple modification to a standard technique (thoracic computed tomography in the prone position) can improve the accuracy of staging the disease in a significant proportion of patients. The results suggest that including both prone and supine computed tomograms in a protocol for staging of oesophageal cancer will reduce the number of patients who are currently falsely diagnosed as unresectable and denied potentially curative operations.

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