

A PHOTOGRAMMETRIC METHOD FOR MEASURING THE CHANGE IN BODY
VOLUME ASSOCIATED WITH ANAESTHESIA

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ABSTRACT

Changes in the volume of the trunk in a group of patients have been determined from stereopairs of photographs taken before and after the induction of anaesthesia. Details of the method are given and the results compared with those obtained by other methods.

INTRODUCTION

Several studies have investigated the influence of anaesthesia on lung volume and most of these have shown a decrease of some 200-700 ml (ie 15-30%) (eg Laws, 1968; Don, 1977). The change occurs rapidly and can be detected in the first few breaths following the induction of anaesthesia. Attempts have also been made to correlate this sudden change with an associated change in external body dimensions by using various mechanical, electronic and radiological methods (Jones et al, 1979; Hedenstierna et al, 1981, 1985; Krayner et al, 1987). So far no consistent changes have been found.

This paper outlines an attempt to measure these changes in external body dimensions by photogrammetry which being a non-contact, spatial measuring technique offers several advantages over the other methods that have been tried. The work was carried out in association with the University Department of Anaesthetics, Royal Infirmary, Edinburgh.

PHOTOGRAPHY AND ANALYSIS

Since all photography had to be undertaken in the preparation room of an operating theatre by medical staff, it was necessary to keep the method of photography as simple and straightforward as possible. An Officine-Galileo A-Special stereometric camera with a base separation of 560 mm was available and it was decided to use this camera to take the photography. The camera was mounted with the base horizontal and camera axes vertical on a rigid gantry such that it was at its closest focusing distance of 1.6 m above the supine patient (Fig 1). The resulting photo scale was 1:10. Agfa-Gevaert Aviophot Pan 60 (13 x 18 cm) photographic plates were used and synchronisation of the two camera exposures was achieved by the use of an electronic flash (Sunpac 33).

Fig 1
Schematic diagram of
the stereometric camera set-up
during the photography of the patient

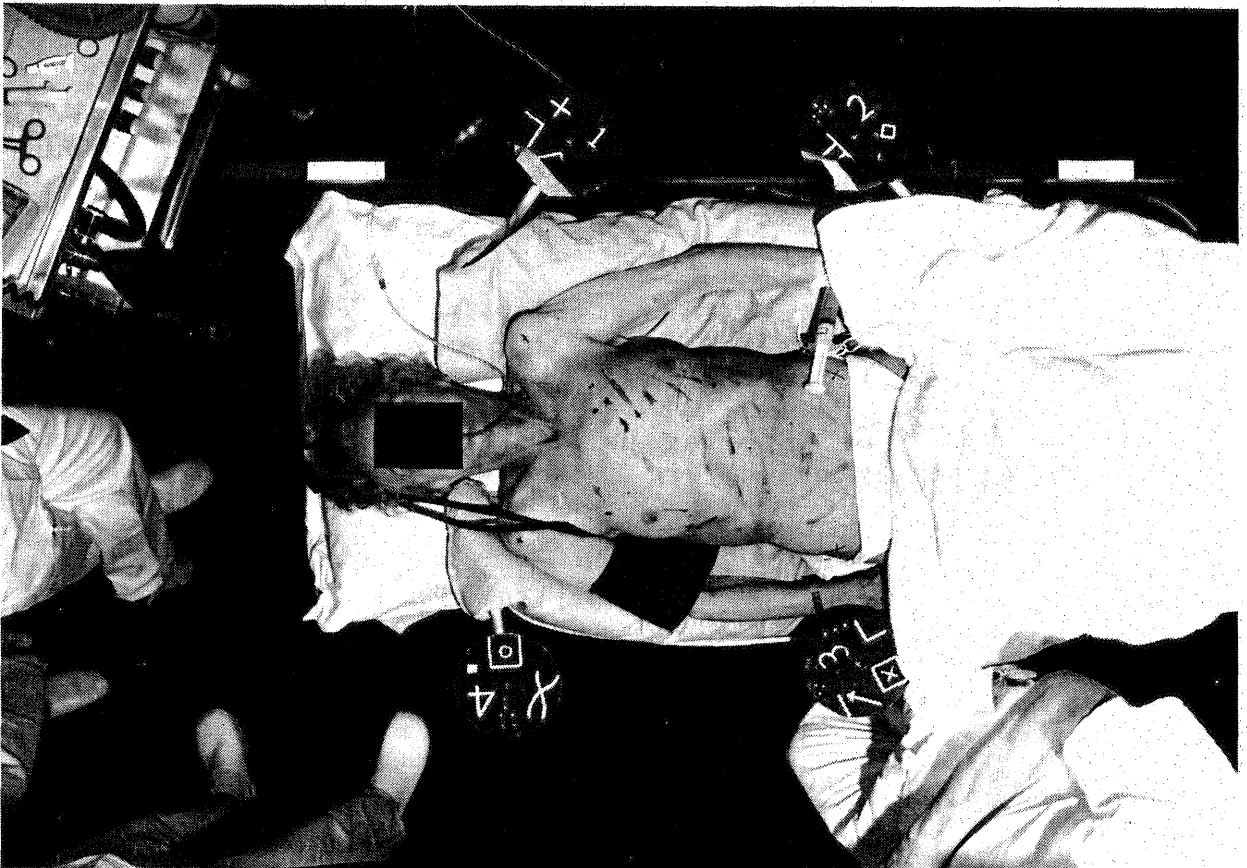
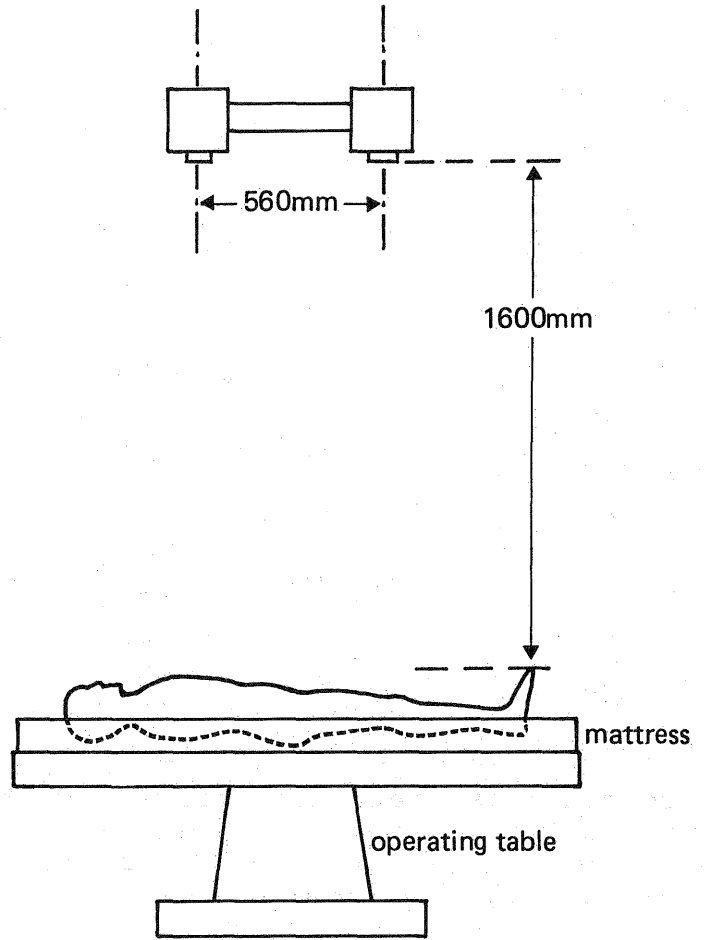


Fig 2 One photograph from a typical stereopair taken during
this study. Note the four orientation targets, the scale bar
and the rigid mattress

It was essential to ensure that no skeletal movement occurred during the period of photography. This was accomplished by using a mattress filled with polystyrene beads (Howmedica Vac-Pac) on the operating table. The supine patient was allowed to relax on this mattress and, as the air was sucked out, the mattress became rigid and moulded to the shape of the back and lower sides of the body. As a further check on skeletal movement, reference points were marked with ink on the skin of the trunk at the anterior superior iliac spines and the humeral heads.

Four targets, firmly attached to the operating table, facilitated relative orientation and provided height control for absolute orientation. A scaling check was provided by a metric scale bar placed alongside the patient.

Breathing affects the external body dimensions and it was necessary to monitor this in order to ensure that the stereopairs of photographs were taken at the same point of the breathing cycle (end-expiration). This was done by monitoring intragastric pressure with a nasogastric tube and displaying the changes on an oscilloscope.

Prior to photography the patient's skin over the chest and abdomen was randomly marked with a brown surgical skin antiseptic (povidone iodine) to improve texture and provide a better surface for photogrammetric observation. The patient was then allowed time to relax and to achieve a stable state of quiet breathing. The first stereopair of photographs was taken at end-expiration using the following technique:-

- (i) Just before end-expiration the camera shutters were opened electronically by solenoid triggers.
- (ii) Exactly at end-expiration the electronic flash was fired manually to provide illumination for synchronous exposure of the two photographic plates.
- (iii) The shutters were closed.

New plates were then placed in the cameras, anaesthesia was induced (using a slow injection of thiopentone 2-4 mg kg⁻¹) and once regular quiet breathing was present, a second stereopair of photographs was taken at end-expiration using the same technique. The time interval between the two stereopairs was approximately 3 minutes. Fig 2 shows one photograph of a typical stereopair.

After processing, each stereopair of photographs (in the form of negatives) was set up in a Wild A7 stereoplotter in the University Department of Surveying, Newcastle upon Tyne. A model scale of 1:4 was chosen and a plotting scale of 1:2 with a contour interval of 10 mm. Contoured maps of the visible parts of the body surface were produced in the normal way for

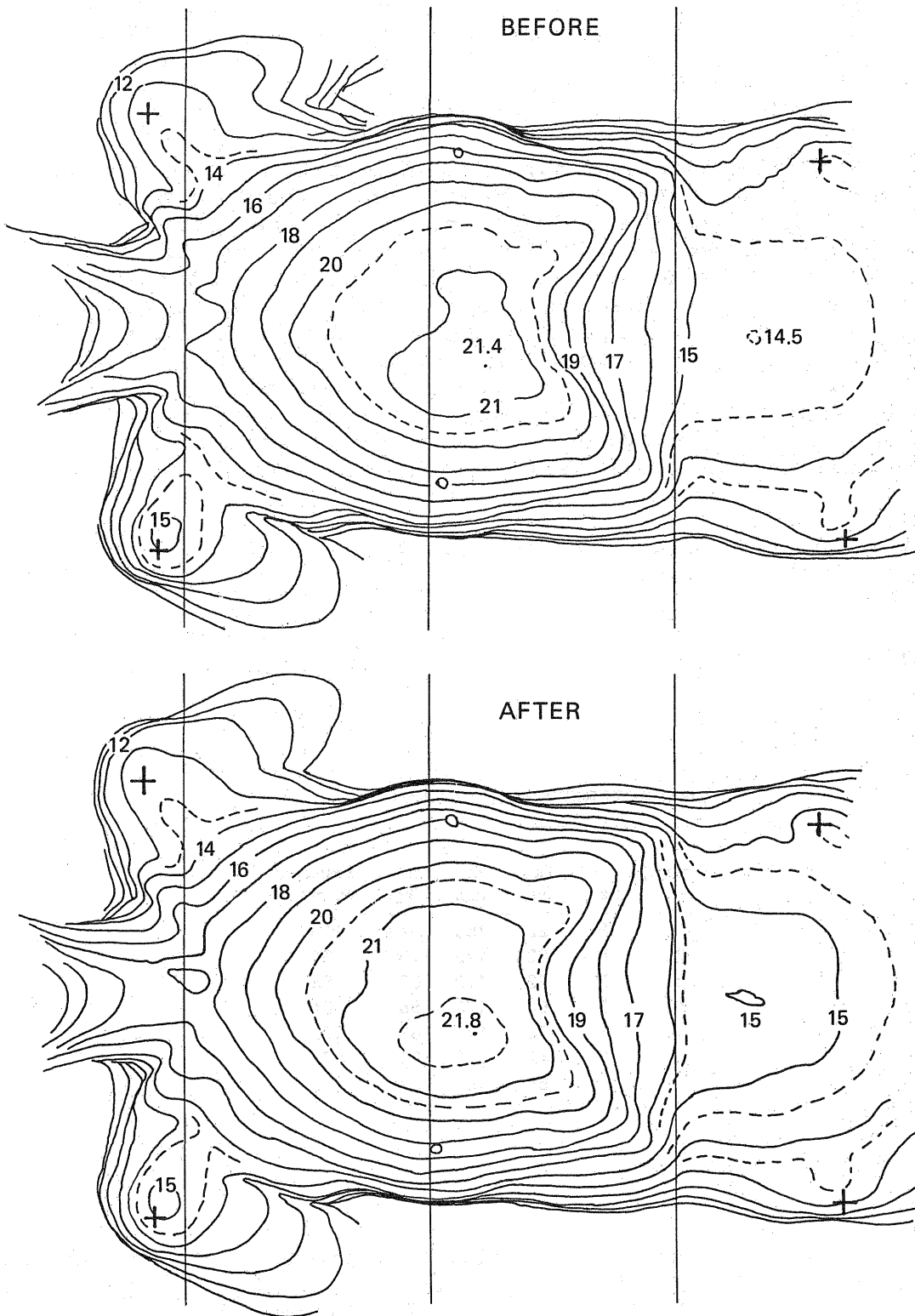


Fig 3 Contoured maps of a patient's body (contour interval 1 cm) before and after induction of anaesthesia. Note the ribcage, middle segment and abdomen subdivisions

each patient before and after induction of anaesthesia (Fig 3). In each case the reference datum for the contours was one of the targets attached to the operating table and checks on skeletal movement were made by reading the heights of the reference points marked on the patient's skin.

Analysis of the contoured maps was undertaken in the University Department of Anaesthetics, Edinburgh. Each contoured map, which extends from the sternal notch to the pubic arch, was divided into three equal portions by drawing in transverse lines as shown in Fig 3. The upper portion approximated to pure ribcage, the middle portion a combination of ribcage and abdomen and the lower portion pure abdomen. The volumes of each of these three portions above the lowest completely visible contour common to the two contoured maps of any patient were determined. In this process the areas were measured using a digitising tablet connected to a BBC microcomputer and the volume computations were based on the end area formula:

$$V = \frac{D}{2} [A_1 + 2(A_2 + A_3 + \dots + A_{n-1}) + A_n]$$

RESULTS

Table I
CHARACTERISTICS OF PATIENTS

Patient No.	Sex	Age (yr)	Ht (cm)	Wt (kg)	% Expected weight
1	F	22	165	67.5	115
2	M	63	175	70	101
3	M	53	170	57	86
4	F	54	173	56	84
5	M	78	171	81	122
6	M	52	179	56	75
7	F	65	158	39	69

Following Area Ethical Committee approval, seven patients agreed to take part in this study and Table I gives their characteristics. Table II lists the volumes measured in the awake state and the changes that occurred with the induction of anaesthesia. The figures show that there was no systematic change in the volume of the total body with anaesthesia or any relationship between volume change and body weight, height, sex or age.

Table II
 MEASURED VOLUME OF TOTAL BODY, RIBCAGE, MIDDLE SEGMENT AND
 ABDOMEN, AND THE CHANGES IN THESE VOLUMES WITH THE INDUCTION
 OF ANAESTHESIA

Patient No.	Total (ml)		Ribcage (ml)		Mid segment (ml)		Abdomen (ml)	
	Awake	Change	Awake	Change	Awake	Change	Awake	Change
1	9088	-352	3373	-186	3467	-59	2248	-107
2	10983	+246	3711	-40	4816	+50	2454	+239
3	10202	+255	3323	+104	4547	-41	2332	+192
4	12788	+77	4297	+342	5366	-160	3125	-105
5	21290	-846	5450	-491	7931	-186	7909	-170
6	12397	-274	4781	-49	5620	-59	1996	-166
7	6456	+505	2386	+252	3431	+92	639	+161

In four of the seven patients however the volumes of all the body portions either increased or decreased. The maximum volume change did not occur in any particular portion but the middle portion never contained the largest change. Further the volume change as a percentage of the volume before anaesthesia showed a significant correlation with obesity in the case of the ribcage. Obesity is here defined as the percentage ratio of the actual weight of the patient to the average (expected) weight for subjects of the same age, height and sex (weight/expected weight x 100%).

DISCUSSION

By using photogrammetry it was possible to take measurements over the whole of the body surface that was visible to the camera (ie slightly less than 50% of the whole body surface) without physical contact. In contrast, most of the methods used in other studies have only allowed measurements at specific points and have required physical attachment of the patient to recording devices and interference with the body surface.

The laying of the patient on a rigid mattress was very successful in minimising skeletal movement. This was confirmed by the constant position of the marked bony prominences both with reference to each other and to the targets. The maximum difference recorded was 1.5 mm but the mean difference was only 0.6 mm. This also suggests that movement of any unsupported portion of the body was minimal and could safely be neglected.

The study found that the volume of the ribcage decreased with anaesthesia in those patients who were heavier than their expected weight. The increase in total body volume detected in four of the patients however was not expected and is difficult to explain since the lung volume is likely to have decreased by 200-700 ml and an increase in volume must have occurred in some other part of the trunk.

A fuller medical discussion of the results is reported in Logan et al (1987).

CONCLUSIONS

Photogrammetry has been demonstrated as a convenient and accurate method for measuring changes in body dimensions and changes in volume associated with the induction of anaesthesia. The results however have shown no consistent change in body volume just like those obtained using other methods. The change in lung volume is apparently not transmitted in any consistent manner to the body surface, if at all, and further research using a larger sample of patients is suggested.

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