ELASTICITY OF LIVING ABDOMINAL WALL IN MINIMAL ACCESS SURGERY

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INTRODUCTION

Deriving the mechanical properties of human tissue from measurements on living subjects is hindered by both ethical and technical difficulties. However, such data are necessary for the development of virtual reality surgical simulation systems that will facilitate both training and treatment planning in minimal access surgery (Satava, 2001), which has many advantages over conventional open surgery and has become an integral part of modern operative surgery (Cuschieri, 2001).

METHODS

Laparoscopic surgery is made possible within the space between the abdominal wall and the internal organs created by inflation with CO_2, it offers a unique opportunity to measure the mechanical properties of living abdominal wall. Two non-invasive techniques were used in this study, so risks and time burdens could be minimized making ethical clearance and patient permission easier to obtain.

Eighteen patients (9 male and 9 female) were included in the study. Twelve infrared markers were placed on half of the abdomen only, symmetry about the midline being assumed. The markers positions were tracked by a system consisting of three infrared cameras. The CO_2 inflation pressure was simultaneously recorded with the flow rate at 1 litre/minute. The measurement sequence was terminated when the pressure reached 12 mmHg, which took about 100 seconds. Furthermore, the abdominal wall thickness of patients was measured outside the operating theatre using ultrasound scanning.

The constitutive stress-strain relationship for abdominal wall can be derived from the measured pressure and displacement data through Laplace's equation (Fung, 1977):

$$\sigma = p r_1 r_2 / 2t(r_1 + r_2) \qquad (1)$$

where r_1 and r_2 are the principle radii of the abdominal wall surface, t is the thickness and p is the relative internal pressure.

RESULTS AND DISCUSSION

The basic data obtained for each patient were age (51/61 years), body mass index, i.e. mass/height^2, (27.5/26.2 kg/m^2), skin/fat thickness (19.2/24 mm) and muscle thickness (12.1/7.4 mm), where the brackets show mean male/female values respectively.

3D-visualisation software was used to trace the paths of the twelve infrared markers. A maximum displacement of 40 mm occurs for the marker at the centre of abdomen. A simulation model of the abdominal wall inflation during laparoscopic surgery has been generated. The software generated a smooth surface passing through the marker points and reflected it in the mid-plane to generate the whole abdominal wall surface.

During inflation, the abdominal wall changed from a cylinder-like shape into a dome-like shape. The average expansion in the area of the abdomen was about 20%. The volume modelling software was used to estimate the volume created by the total expansion, outward movement and reshaping of the abdominal wall. On average, this volume was 1.27×10^{-3} m^3.

Average values of stress and strain for the male and female patients are plotted in figure 1. The mean Young's modulus was 26.6±4.3kPa and 18.1±2.5kPa for males and females respectively (error expressed as ± two standard errors).

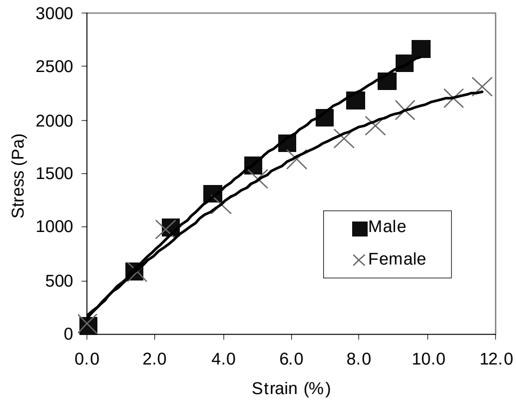

Figure 1. The stress-strain relationship of abdominal walls showing the male abdominal wall to be stiffer than the female's.

SUMMARY

The minimal access surgery offers an unique opportunity to measure the mechanical properties of living subjects. For the first time, the elasticity of human abdominal wall was obtained from the hospital patients undergoing laparoscopic surgery.

REFERENCES

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