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base-line impedances are usually of a similar order of magnitude, the intra-thoracic signal to noise ratio is clearly much better, by a factor of approximately 25 (Table, which is taken from the end-expiratory phase of Figs a and b). This should be of direct benefit to the

	$\triangle Z$ (ohm peak-peak)	Z_o (ohm)	$\triangle Z/Z_o$
Intra-thoracic	4.6	19	0.24
Trans-thoracic	0.3	28	0.01

computation of stroke volumes and cardiac outputs. It is hoped to achieve results comparable with the clinically accepted thermal dilution method of measuring cardiac output.

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INTRA-THORACIC IMPEDANCE PLETHYSMOGRAPHY AND CARDIAC OUTPUT

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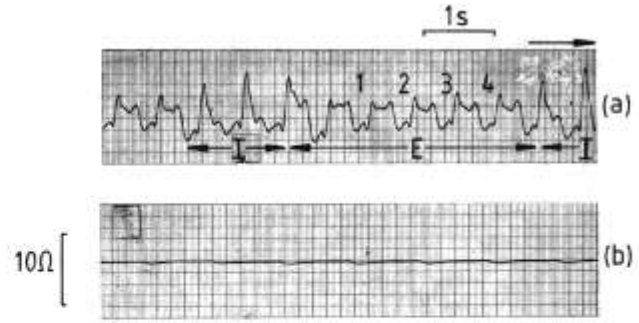
Oesophageal catheter probes provide an established method of measuring variables such as ECG, temperature, heart and breath sounds, diaphragmatic EMG, and electrical impedance.[1-3] Various advantages for such oesophageal (intrathoracic) probes have been stated, the most important of which are that they are non-invasive (at least in the unconscious patient) and that they provide a simple patient-instrumentation interface which remains outside the sterile field during surgical operations. Insertion of an appropriate oesophageal probe is generally easier and quicker than applying a multi-spot electrode array or metal-foil bands as is required for the conventional trans-thoracic impedance measurement. In the intra-thoracic method, 5-10% of the impedance signal is a pulsatile component compared with 0.2% for the trans-thoracic method.[4] Although some workers have doubts about the accessibility of blood volume information from the impedance signal,[4] there is ample evidence to the contrary, [5, 6] and a successful trans-thoracic impedance cardiac output monitor has been developed.[7] By comparison the oesophageal (or intra-thoracic) impedance signal has been poorly documented, as this site for the

probe is a new approach for thoracic impedance. Since the oesophageal impedance differs in several respects from the trans-thoracic signal, further work is required to establish a simple method for measuring cardiac output. The aim of this study has been to document the better signal-to-noise ratio from the intra-thoracic impedance signal when compared with the trans-thoracic, which should allow better measurements of cardiac output.

Materials and methods. The oesophageal impedance probe consists of an Oxagon oesophageal stethoscope that has a linear array of four thin-film silver electrodes incorporated into its plastic tube wall towards the distal end.[8] The electrodes are connected to an impedance analyser of the Thevenin constant current type,[8] which has many advantages over earlier designs, including linear response and a calibration that is independent of the impedance value over the physiological range. The outer two electrodes provide a constant current in the thoracic tissue (4 mA_{rms} at 100 kHz), while the inner two provide voltage sensing. The constant current ensures that the magnitude of the tissue impedance is proportional to the sensed potential difference across it. A chart recorder is used to plot the smoothed basal impedance, Z_o, the pulsatile component of the impedance, $\triangle Z$, and the rate of change of the pulsatile component, dZ/dt. Our impedance analyser is based on an instrument developed at Monash University, with modifications in order to cope with the larger impedance changes observed via the intra-thoracic route.

Results and discussion. Our intra-thoracic impedance analyser typically shows a peak to peak pulsatile impedance change of about 5 ohms during a cardiac cycle (Fig. a). When the same impedance



Sample thoracic impedance waveforms. Waveform (a) was obtained using the oesophageal probe while waveform (b) was obtained using external electrodes. Note the greater magnitude of the pulsatile impedance signal in (a) compared with (b). Although the intra-thoracic waveform has a larger respiration artifact than the trans-thoracic waveform, typically 3 or 4 cardiac cycles are usable during expiration. I = inspiration; E = expiration.

analyser is connected via electrodes to the thorax to give a trans-thoracic impedance measurement, the pulsatile cardiac component is typically only 0.3 ohms (Fig. b). Since the intra-thoracic and trans-thoracic