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Reappraisal of the Utility of the Tilt-table in the Investigation of Venous Disease[†]

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WHAT THIS PAPER ADDS

Air plethysmography is currently not considered a useful clinical instrument in the investigation and quantification of venous disease. This is because of lack of standardisation, poor reproducibility, patient movement artefacts, and historical evidence that it cannot quantify obstruction. The tilt-table is reintroduced. Gravitational challenges are standardised and the patient remains stationary on the moving table. Furthermore, standardisation of elevation drainage with the new venous drainage index is made possible to quantify venous obstruction. Advances in the quantification of venous insufficiency with plethysmography and duplex ultrasound, with the tilt-table, will have a direct impact on research and clinical practice.

Objectives: Without gravity opposing drainage, most venous diseases would not exist. Therefore, manoeuvres that assess venous function should include gravity. The aim was to "dose" gravity in subjects using static positions and dynamic angulations on a tilt-table and to assess its effects with air plethysmography (APG) and duplex ultrasound over the femoral vein.

Methods: Three groups (providing $n = 11$ legs each) were compared. (a) A control group, without clinical or duplex evidence of venous disease. (b) An obstruction group, with past iliofemoral deep vein thrombosis. (3) A reflux group, with primary varicose veins. A manually operated tilt-table ranging from -70° to 40° in the Trendelenburg position provided rapid tilting (<3 s). The changes in calf volume at -70° (almost standing), -45° (reclining), and 40° (legs-up) were recorded with APG, as well as the rate and duration of the changes. The minor diameter of the femoral vein was recorded at the three tilt positions.

Results: The results were expressed as median (interquartile range). The total working venous volume (mL) in the reflux group was significantly increased: 202 (180–240) mL versus the controls at 138 (119–198) mL, $p = .008$, and versus the legs with obstruction at 117 (80–154) mL, $p < .0005$. The venous drainage index (VDI) in mL/second in the obstructed group was significantly reduced: 7 (6–9.6) mL/second, versus the controls at 17.4 (13.9–27.2) mL/second, $p < .0005$, and versus the legs with varicose veins at 28.1 (25.4–34.4) mL/second, $p < .0005$. The venous filling index (VFI) in mL/second in the reflux group was significantly increased: 8.1 (4.2–10) mL/second versus the controls at 1.8 (1–2.1) mL/second, $p < .0005$. The VDI cut-off point discriminating obstruction was $\leq$10.8 mL/second and the VFI discriminating reflux was $\geq$ 2.9 mL/second. The femoral vein diameter was reduced significantly with increasing leg elevation.

Conclusions: Manoeuvres using APG on a tilt-table have the potential to quantify the contributions of global obstruction and reflux (mL/second) in patients with venous disease.

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INTRODUCTION

The venous network of the leg is a complex system of interconnecting tubes whose prime function is drainage. However, this differs from most conventional systems in that venous drainage is upwards against the force of gravity rather than reliant on gravity. Factors that cause drainage insufficiency include retrograde flow (reflux) and

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compression of the outlet tubes (obstruction). Poor cardiac or leg muscle pumping and venous scarring (reduced tone) from a previous deep vein thrombosis (DVT) are also important contributing factors but less easy to standardise and quantify reliably. Nevertheless, without gravity hampering drainage, most of the usual venous diseases like varicose veins would be rare.

The tilt-table is a device that can standardise the *dose* of the gravitational force by the degree of tilt and also by the rate at which the tilt changes. Since the precipitating cause of most venous disease is gravitational, it is intuitive that a gravitational test should be the principal manoeuvre for most haemodynamic and imaging investigations on the venous system.

The aim of this study was to use simultaneous air plethysmography (APG) and duplex ultrasound scanning on a tilt-table to assess the effects of gravity in control patients, patients with obstruction, and patients with superficial venous reflux. This expands upon the qualitative tilt-table work of J. C. Allan, who reported in 1964 the changes in the volume of the calf in normal subjects and patients with post-DVT ulcers and varicose veins, using APG.[1]

METHODS

Study design

This was a collaborative, prospective, proof-of-concept study performed in Wunstorf, Germany.

The study was approved by the regional ethics committee (REC) of the State Medical Chamber of Lower Saxony, Germany. Participants were given an information leaflet to read and signed a consent form. Once the basic demographic details were completed, the calf volume each subject was measured (Bodytronic 600, Bauerfeind AG, Zeulenroda-Triebes, Germany) and a full duplex examination performed standing. This included an assessment of infra-inguinal reflux, defined as reverse flow lasting $>$ 0.5 s in superficial veins[2] and $>$ 1.0 s in deep veins,[3] after a calf compression and release manoeuvre. Evidence of obstruction on duplex was indicated by wall thickening, segments of no flow, hyperechoic areas within the lumen, incomplete compressibility, and the presence of dilated pelvic venous collaterals. The femoral vein diameter was measured below the saphenofemoral junction (SFJ), and the great saphenous vein (GSV) diameter was measured at the proximal thigh, 15 cm below the groin crease.[4]

The set-up consisted of a tilt-table in the centre of the room, a duplex ultrasound scanner (Fazone CB; Fujifilm, Düsseldorf, Germany) attached to a linear 7.5-MHz transducer probe on one side, and the APG apparatus (ACI Medical LLC, San Marcos, CA, USA) on the other, to facilitate simultaneous assessments. The actions of the tilt-table were rehearsed with each participant, first with the table unoccupied and then with the subject in position. One-second intervals were counted out loud so that each subject was aware of the speed of angulation for each position.

Participants

Three groups, with 11 subjects (11 legs) in each group, were tested: (a) a control group without clinical evidence of venous disease. They had no reflux or obstruction on duplex ultrasound. (b) An obstruction group following a documented past occlusive iliofemoral DVT, with duplex evidence of groin or pelvic collaterals. Inclusion was irrespective of aetiology, previous venous surgery, or past intervention. (c) A reflux group with primary varicose veins from a refluxing GSV. These were patients who sought treatment for their varicose veins without prior intervention and without evidence of a past DVT.

Exclusion criteria were severe concomitant medical illness, pregnancy, vertigo, significant neurological disorder, stroke, and postural hypotension.

Tilt-table

The tilt-table is shown in Fig. 1. The tilt-table (Karlheinz AltenkircH, Wiedenbrügge, Germany) was manually operated with an adjustable counterweight for rapid tilting ($<$3 s). Design features include a foot platform for the subject to step onto with a cushioned heel raise to make room for the APG sensor cuff. An adjustable neck and shoulder support with a safety handle provided comfort and confidence against slippage in the Trendelenburg position. The external frame housed a stabilisation pin to keep the table neutral for calibration and gave the subject a reference point to minimise disorientation. Body straps were not

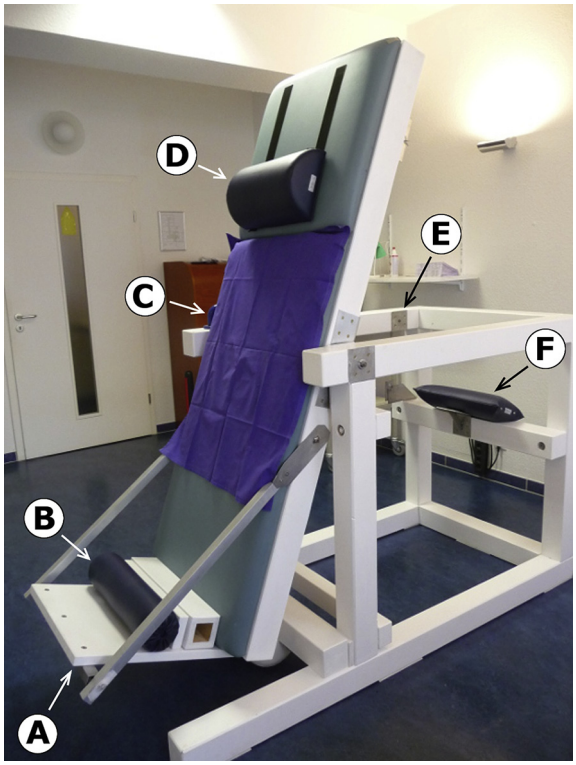

Figure 1. The manually operated tilt-table for rapid tilting manoeuvres (−70° to 40° Trendelenburg). (A) Foot plate; (B) bilateral heel support; (C) confidence safety handle; (D) adjustable head and shoulders support; (E) horizontal fixation pin socket; (F) head-down table support cushion.