Original article

Rhys-Davies exsanguinator: effect of age and inflation on performance

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We found that the Rhys-Davies exsanguinators in our local hospitals were poorly maintained (inflation pressure, storage conditions, replacement age) when compared to the manufacturers' recommendations. In a volunteer study, we demonstrate how the inflation pressure and age of an exsanguinator affect its performance.

Key words: Exsanguination – Upper limb – Pressure

The Rhys-Davies exsanguinator is a quick, safe and effective method of exsanguinating a limb prior to tourniquet inflation and surgery. Although used widely throughout the UK for over a decade, little has been published on it. Consisting of a permanently inflated rubber sleeve, it is simply rolled up the limb, squeezing the blood proximally as it proceeds. Manufactured from cured natural rubber, it can be washed in soap and water or antiseptic solutions but should not come into contact with solvents. It cannot be autoclaved.

Over a period of time, typically months, the pressure exerted by the exsanguinator can drop. This is due to slow air loss and some stretching of the elastomer. Elastomer degradation (break down of the polymer cross-links) is affected by frequency of use, storage temperature, and by exposure to both UV light and ozone (the latter can be generated by electrical equipment). The manufacturers, therefore, advise that the exsanguinator is stored inside its polythene bag to reduce these effects. The first signs of elastomer degradation are cracks on the surface. With

time, the exsanguinator will eventually split/burst. This is most likely to happen when it is being topped up with air

Figure 1 The exsanguinator is connected to a manometer by the inflation kit (the needle is inserted into a valve in the wall of the exsanguinator).

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MONTHLY CHECK LIST

- Ensure product is clean and suitable for next application.
- Pressure should equate to 60mm/Hg. Refer to instruction leaflet enclosed for guidance.
- Visually inspect the unit for signs of cracking or splitting. If so refer to supplier.
- The recommended period of use of this device is 12 months.

CONTENTS

1 x Rhys Davies Exsanguinator

1 x Inflation Kit

1 x Blue Polythene Bag

1 x Tape Measure

1 x Instruction Leaflet

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 10	Month 11	Month 12	
Checked By:	Checked By:	Checked By:	Checked By:	Checked By:	Checked By:	Checked By:	Checked By:	Checked By:	Your Rhys - Davies Exsanguinator should now be replaced
Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:	

Figure 2 Printed section on the cardboard box for recording exsanguinator maintenance.

or being rolled onto a patient’s limb. The manufacturers, therefore, recommend that the exsanguinator be replaced annually, although such a figure is unsupported by any scientific work. Exsanguinator inflation is periodically checked by connecting the re-inflation kit (a blunt ended hollow needle, tubing and hand pump, which is supplied with the exsanguinator) to a manometer (Fig. 1). The manufacturers suggest an inflation pressure of 60 mmHg, although there is no published data to support this pressure over any other. As a simpler alternative, the degree of inflation can be checked by feeling the exsanguinator’s tension or by measuring its external circumference (when new, 46–47 cm corresponds to 60 mmHg). Printed on the storage box is a section that allows a record to be kept of exsanguinator maintenance (Fig. 2). A serial number (from which the date of manufacture can be ascertained) is printed on both the exsanguinator and on the box.

Figure 3 Inflation pressures of the 17 exsanguinators audited. The manufacturers recommend 60 mmHg.

We have compared the maintenance of our local Rhys-Davies exsanguinators with the manufacturers’ recommendations and investigated the validity of these recommendations by studying how the inflation pressure and age of an exsanguinator affect its performance.

Audit of exsanguinator condition

Methods

We audited 10 Mersey-Region Hospitals (6 trusts), with a single unannounced visit for each. A total of 17 exsanguinators were studied. We measured the inflation pressure, noted whether or not the exsanguinator was stored correctly, and attempted to ascertain the exsanguinator’s age.

Results

The condition of most of the exsanguinators was in contrast to the manufacturers’ advice. All were under inflated, with nearly half of them being half-inflated or less (Fig. 3). Only 4 of the 17 still had their polythene bag, which was not necessarily used. Only 3 boxes had been kept, of which all had nothing written in their ‘maintenance history’ sections. Two of the 17 exsanguinators were under a year old, 2 were between 1–2 years old and 5 were over 2 years old. In 7 cases, age was unknown because of an absent serial number and box, but all looked a couple of years old. None of the hospitals changed their exsanguinators on a yearly basis, with many keeping them until they burst/split.

Study of exsanguinator performance

Materials and methods

In a study that was conducted over a 1 month period (May–

Figure 4 Standardised position of the pressure-recording bags: palm (a) and extensor aspect of the mid-forearm (b).

June 2000), we compared 3 Rhys-Davies exsanguinators of different ages – they were 6 months, 12 months, and at least 2 years from manufacture – using the upper limbs of 10 healthy volunteers aged 25–40 years (mean, 29 years). Each volunteer was tested once, using the left arm for all, in a sitting that took approximately 1 h (totalling 190 exsanguinations). The pressure produced by the exsanguinator on the skin was measured objectively, using a simple pressure transduction set-up. This consisted of small air-filled bags (50 ml) taped to the skin of the palm and forearm (Fig. 4) and connected by thin tubing to a mercury manometer. As the exsanguinator was rolled up the arm, the peak pressures produced at these sites were recorded. Five consecutive exsanguinations were performed in this way and the mean peak pressure was calculated.

Starting with an exsanguinator inflated to 80 mmHg, peak pressure exerted by it on the palm and forearm were recorded as above and the mean calculated. The exsanguinator was then deflated in 10 mmHg increments, obtaining the mean peak pressures at each level and stopping at 20 mmHg. Each exsanguinator was tested in turn in the same fashion. The oldest exsanguinator, however, could not be inflated above 64 mmHg, with attempts to do so simply resulting in its walls ballooning (Fig. 5). Therefore, for this exsanguinator, testing was started at 60 mmHg.

To give an indication of the state of the exsanguinator material itself (*i.e.* its rubber walls), we measured its external

diameter at each inflation pressure, measurements being taken at 3 constant points along its length and the mean value used.

Results

For all 3 exsanguinators, the relationship between their inflation pressure and the resultant pressure exerted on the skin was a relatively linear one, in the range studied. Figure 6 shows the pressure profiles produced by the 6-month-old exsanguinator in the 10 volunteers. A similar

Figure 5 Both exsanguinators are inflated to 60 mmHg. Note the ballooning of the wall of the oldest exsanguinator (left) compared to the newest (right), which made this exsanguinator difficult to pass at any inflation pressure above 40 mmHg.

Figure 6 Pressures produced by the 6-month-old exsanguinator for the 10 volunteers.

Figure 7 Mean pressures produced by the 3 exsanguinators of different age.

interindividual pressure range was observed for the other 2 exsanguinators. To compare the performance of the 3 exsanguinators, the average of the 10 values was used, as shown in Figure 7.

There was no difference in performance between the 6- and 12-month-old exsanguinators. Although still working, the oldest exsanguinator is clearly inferior, with the linear

relationship between inflation and exerted pressure failing at the top inflation.

The relationship between exsanguinator inflation pressure and external diameter is also essentially linear (Fig. 8), with no difference again between the 6- and 12-month-old exsanguinators but with the oldest exsanguinator showing evidence of elastomer deterioration.

Figure 8 Exsanguinator size as a function of its inflation pressure.

Discussion

The Rhys-Davies exsanguinator has been in use since the early 1980s.¹⁻³ Initial volunteer studies, using strain gauge plethysmography and skin pressure recording, suggested that it gave better exsanguination than simple limb elevation and, in contrast to the Esmarch bandage, compressed the limb in a uniform manner at a safer pressure.¹ There has been only one reported complication from its use, a longitudinal split in the skin of the posterior calf in a female with rheumatoid arthritis.⁴

Exsanguinator inflation

The pressure required for optimal surgical limb exsanguination is unknown. It has been shown that an Esmarch bandage can produce pressures of 200–300 mmHg in the upper limb.¹ According to Tyler, only about 100 mmHg pressure is required for effective exsanguination. He states that the Rhys-Davies exsanguinator was developed around the premise that only 85–95% of the blood in a limb should be exsanguinated.³ An initial inflation pressure of 60 mmHg was thus chosen. However, there is no scientific work to support any of these specific figures. Others have also suggested that 'over' exsanguination of the limb may be detrimental, making the surgical anatomy less clear. Colville and Small⁵ compared 4 methods of upper limb exsanguination in a randomised blind trial of 100 patients undergoing elective hand surgery. Although 3% of patients were graded

as 'over' exsanguinated, none of these were from the Esmarch bandaging group, the method most likely to produce such a result.

All of our exsanguinators were under inflated, some significantly, when compared to the manufacturer's recommendation. Their continued use in this state suggests that the quality of the exsanguination is acceptable even when under inflated.

Our study provides reference values for the pressure exerted on the upper limb for a given exsanguinator inflation pressure.

Exsanguinator replacement

None of our exsanguinators had been replaced, as recommended, on a yearly basis and this did not appear to have resulted in any problems. However, the authors know of at least 3 occasions of an exsanguinator bursting whilst being used on a patient. This makes quite a loud noise. In the case of procedures done under local anaesthesia, such an event would be distressing for the patient. In addition, the exsanguinator contains a silicone lubricant (liquid), which could spill out onto the patient's limb.

Our study found no difference in performance between the 6- and 12-month-old exsanguinators. Even the old, stretched exsanguinator (> 2 years) was able to produce reasonable pressures on the limb, although it was more difficult to pass because of its bulk.

Conclusions

The Rhys-Davies exsanguinator remains an important piece of orthopaedic theatre equipment. However, in our experience, its maintenance and periodic replacement are all too often neglected.

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