Inflatable splints—what are they doing?

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SUMMARY

The pressure to which splints were inflated was measured to determine whether splintage was effective and if vascular complications were likely. The prevalence of their use by the ambulance service was also investigated. The findings indicate that inflatable splints are in common use, and are rarely inflated to pressures likely to cause vascular complications. However, they are extremely inefficient in holding their pressure and rapidly become ineffective as splints. The therapeutic range between effective splinting and risk of complications is narrow and it is recommended that blow-off valves are incorporated into the manufacture of all such devices.

INTRODUCTION

Inflatable splints were first described by Curry (1944). Fears about vascular damage were expressed at the time and these limited their use. However, they gradually became more popular with ambulance crews and other providers of immediate medical care in this country and the polythene versions currently in use are similar to those described by Gardner (1962). Amongst their advantages are their small size and their ease of use. Ashton (1962, 1963) published work concerning Critical Closing Pressure (CCP) in human vasculature. She also investigated the phenomena surrounding the re-opening of blood vessels when uniform pressures were applied to the limb. At room temperature the mean pressure at which closure occurs is 33.4 mm Hg in the forearm, 22.7 mm Hg in the finger and 21 mm Hg in the calf. At these pressures some blood flow resumed after 30–60 s but if the CCP was exceeded by 5–10 mm Hg, no flow resumed even after prolonged periods. These pressures do not occlude normal arteries but interrupt the connections between artery and vein and thus produce ischaemia. Ashton (1966) also observed that with a mean blood pressure of 95 mm Hg, a splint inflated to 40 mm Hg

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would reduce the transmural mean arterial pressure to 55 mm Hg, and would result in marked reduction in blood flow. If, therefore, the blood pressure is initially low due to hypovolaemic shock, the blood flow may cease entirely. Manufacturers of the splints claim that pressures of 30–40 mm Hg are safe and that pressures above this are unlikely to be achieved by inflation by mouth. However, Ashton (1966) inflated splints on 12 normal subjects' arms and calves and found complete cessation of flow at 40 mm Hg in five limbs and dramatically reduced flow in the remaining seven. She also commented that inflation pressures much below 30 mm Hg provide poor support for fractures, but this observation does not appear to have been based on clinical evidence.

London (1966) and Gardner (1967) questioned the relevance of doubts about circulation because clinical use had not demonstrated harmful side effects.

Since their introduction two modifications have been described. The first was by Ashton (1968), who suggested that a fluted splint would be safer. The second, by Patrick (1978), was a fluted lower limb splint with the forefoot exposed to allow observation of the distal circulation.

MATERIALS AND METHODS

The pressure in the splint was measured using a mercury sphygmomanometer connected to the air inlet tube of the splint. A recording was made as the patient arrived in the accident and emergency department, the splint having been applied by ambulance men at the scene of the accident. To assess the likely initial inflation pressure the ambulance men also inflated splints on normal limbs and the pressure achieved was recorded.

To measure the pressure necessary to maintain effective splinting, cadaver lower limbs were used. Articulation was achieved by surgical division at the knee and a full length inflatable splint was applied. This was inflated until the leg remained horizontal.

Finally, nine chief ambulance officers were asked whether these splints were still in use and if so, what kind were being issued.

RESULTS

Cadaveric limbs which had been divided at the knee were found to remain horizontal with support at the thigh when the pressure reached 20 mm Hg. This was a constant and reproducible figure.

Patients presenting to the department (Table 1) had pressures between 0 and 22 mm Hg in arm or leg splints (mean 10.07 mm Hg). Splints applied by ambulance men to volunteers (again both leg and arm splints) were inflated to between 8 and 35 mm Hg (mean 19.46 mm Hg). The difference between these two groups is significant at the 0.01 level (Wilcoxon rank sum test). There was no difference in pressure between the arm and leg splints.

Splint usage in the nine regions contacted is fairly consistent. Eight regions use rigid inflatable splints and one does not use them at all. Two regions of the eight indicated that they were phasing out the splints. One region also used fluted splints (Table 2).

Table 1 Inflation pressures in splints used on patients and on volunteers ($p < 0.01$ —Wilcoxon rank sum test)

Patients		Volunteers	
Type of splint	Pressure (mm Hg)	Type of splint	Pressure (mm Hg)
Full Leg	18	Full Arm	20
Full Leg	4	Full Arm	35
Full Arm	5	Full Arm	8
Full Arm	12	Full Arm	20
Full Arm	14	Full Arm	10
Below Knee	10	Full Arm	20
Below Knee	0	Full Arm	24
Below Knee	1	Full Arm	20
Below Knee	10	Full Arm	16
Below Knee	8	Full Arm	25
Below Knee	22	Below Knee	18
Below Knee	16	Below Knee	24
Below Knee	11	Below Knee	14
Below Knee	8	Below Knee	28
Below Knee	12	Below Knee	10
Mean	10.07	Mean	19.46

Table 2 Splint usage by nine chief ambulance officers

County	Type of splint	Comment
Derbyshire	rigid	few fluted
South Yorkshire	rigid	phasing out
Leicestershire	rigid	
Lincolnshire	rigid	phasing out
Nottinghamshire	rigid	
Mersey Metropolitan	not used	
Cheshire	rigid	
Greater Manchester	rigid	
Lancashire	rigid	

DISCUSSION

Nearly 20 years after warnings concerning their safety, pneumatic splints are still in widespread use. Fluted splints were recommended as being physiologically safer

(Ashton, 1968), but these are not common and the Urias (Urias Manufacturing Co Haarlev, Denmark) rigid splint is by far the most commonly used. It is small, rugged and has a long service life.

Inflation pressures on the volunteers are assumed to be the pressure to which the splints are inflated by the ambulance crews at the scene of an accident. Most splints leak and in many the air can be heard escaping past the pinch-cock mechanism. Thus pressures in splints on patients arriving in the accident and emergency department are lower than initial inflation pressures, the drop presumably depending on the time that has elapsed since inflation. We estimate that most of our patients arrive in our department within 20 min of the splint being applied.

The actual pressure measured in both groups is considered safe, with the possible exception of one case in the volunteer group when a pressure of 35 mm Hg was measured. The CCP is 21 mm Hg in the calf, and this has to be exceeded by 5–10 mm Hg before complete cessation of flow occurs. Hence pressures above 25–30 mm Hg may be considered unsafe. Pressure tends to drop rapidly enough for this not to be a major problem. It is unsatisfactory, however, to rely on faults in the equipment to guarantee its safety.

It is important that people who will apply the splint are aware of potential hazards. Training is important but it is difficult to give strict guidelines about inflation. In an American Paramedical Textbook Caroline (1979) suggests that they should be inflated until the wall of the splint can be dented by pressure from the fingertips. We have found this pressure to be considerably in excess of that likely to cause vascular damage.

The manufacturers' claim that pressures up to 40 mm Hg are safe is doubtful. They also claim that pressures above this are hard to achieve by mouth. We have readily inflated splints to 80 mm Hg although one would be most reluctant to use this kind of pressure on an injured limb.

The force applied to the cadaveric limbs was gravitational pull on the leg and is not strictly comparable to the forces that may occur during transport of a patient. However, a pressure of 20 mm Hg will provide considerable protection and the mere presence of an inflatable splint will provide a powerful reminder to those caring for the patient that they must be handled with care.

One could be assured of the safety of these splints if a valve was fitted which automatically leaked air if the pressure was above 20 mm Hg.

In spite of these doubts, we believe that current usage of splints is safe. We can find no recorded case of complications arising from their use in 20 years, a comment which applies to very few therapeutic devices. However, at present they are safe only because they leak and if they were efficient in retaining their pressure they would be dangerous. The therapeutic range between effective splinting and the risk of complications is narrow and at present splintage is effective for a very short time. Safety could be improved by incorporating a 'blow-off' valve into the device and efficacy improved by greater quality control.

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