ADVERSE EFFECTS OF BUFFERED GLUTARALDEHYDE ON THE HEIDBRINK EXPIRATORY VALVE

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SUMMARY
The effect of chemical disinfection of the Heidbrink expiratory valve in buffered glutaraldehyde (Cidex solution) was investigated. Cidex caused stickiness and increased the opening pressure and resistance of the valve to different gas flow rates. An electrolytic type of corrosion may also have occurred. However, autoclaving of the Heidbrink valve did not appear to cause corrosion or significant alteration of its opening pressure or resistance.

The use and efficiency of buffered glutaraldehyde (Cidex) as a chemical disinfectant for anaesthetic equipment have been described by Haselhuhn, Broson and Borick (1967), Meeks, Pembleton and Hench (1967) and Stark (1972). Residual air, wetness and the need for rinsing and packaging after disinfection are among the disadvantages of chemical disinfection described by Lumley (1976). Apart from absorption by rubber and plastics (Varpela, Otterström and Hackman, 1971), Cidex was reported to be non-corrosive to metals and harmless to anaesthetic equipment. It was observed in our hospital that, despite the Heidbrink valves (Mushin and Mapleson, 1954) being adjusted to the fully open position, many of them were sticking and hissing loudly. As the valves were routinely disinfected in Cidex solution, this investigation was undertaken to determine if this method of disinfection was responsible for the above problem. Changes in the opening pressure and the resistance of each valve to different gas flow rates (expressed as the pressure decreases across the valve) were also measured.

METHOD
Sixteen valves were investigated. Six of these were 2–3 years old and were routinely disinfected in Cidex solution (group I). The other 10 valves were new (group II). These were equally divided into two groups. Following their use during anaesthesia, the new valves of each group were washed thoroughly in water then sterilized either by autoclaving (group III) or by immersion in Cidex solution (group IV). The valves in group IV were further rinsed in water following sterilization in Cidex.

A technique similar to that described by Mushin and Mapleson (1954) was used to measure the opening pressure and resistance of the old valves (group I) to different gas flow rates employing a calibrated oxygen flowmeter and U-tube water manometer, the valves being in the upright position. Naked eye and microscopic examination of each valve disc and pin were performed. The new valves were investigated similarly both before (group II) and 10 months after their use in clinical practice (groups III and IV). Furthermore, the discs of two valves from group I and IV and one valve in group III were also examined under a Stereoscan electron microscope.

RESULTS
The mean opening pressure and resistance for a given gas flow rate for each group of valves are presented in table I. For a given flow rate the mean resistances of the valves in groups I and IV were approximately twice those in groups II and III. In the clinical range of gas flow rate (30 litre min⁻¹) the mean pressures were 0.78, 0.28, 0.28 and 0.66 kPa in groups I, II, III and IV respectively. Similarly, the mean opening pressures of the valves in groups I and IV were greater than those in groups II and III. The values were 0.56, 0.08, 0.10 and 0.28 kPa for groups I, II, III and IV respectively.

Naked eye examination
Group I. The changes in the discs and pins of the valves are typified by valve D (fig. 1). Both surfaces of each disc were dull in appearance. The disc and its pin appeared to be diffusely covered by a thin film of foreign substance. A number of irregular black areas 0.5–2 mm in diameter were present on both surfaces of the disc, particularly near its centre. These were obviously caused by corrosion.

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Fig. 1. Four Heidbrink valve discs. Disc A: new valve (group II). Disc B: new valve sterilized by autoclaving (group III). Disc C: new valve disinfected by Cidex (group IV). Disc D: old valve in group I also disinfected by Cidex showing signs of corrosion.

Group II. The disc and pin surfaces of the valves in this group were smooth, bright in appearance and free from cracks or foreign substances (valve A, fig. 1).

Group III. No major differences between the discs and pins of the valves in this group and those in group II were seen (valve B, fig. 1).

Group IV. The discs and pins appeared dull and covered by a substance similar to that found on the discs in group I (valve C, fig. 1), but no black areas in the discs were seen.

Microscopic and Stereoscan electron microscopic examination

Group I. Several aggregated particles of variable size and shape were seen, scattered diffusely on both surfaces of each disc and its pin. Pitting and cracking of the disc surfaces were found (fig. 2).

Groups II and III. The surfaces of the discs and pins of the valves in both groups appeared irregular but smooth and free from pits, cracks or deposits of foreign substance (fig. 3).

Group IV. Particles similar to those found on the discs of the valves in group I were also seen on the discs and pins of the valves in this group. Only a few pits, but no cracks in the disc surfaces were present (fig. 4).

DISCUSSION

In semi-closed systems the resistance to expiration resides in the Heidbrink valves. A high resistance to expiration will eventually lead to an increase in the work of breathing. Nunn (1969) suggested that, at gas flow rate of 30 litre min\(^{-1}\) the pressure decrease across the expiratory valve should not exceed 0.29 kPa. The resistance in all the valves in group I at that flow rate exceeded this value (table I). Furthermore, the mean resistance of the valves in group IV (after 10 months of clinical use) at the same gas flow rate had doubled and exceeded 0.29 kPa. Only a small change was found in resistance of the valves in group III after a similar period of usage.

When rendered alkaline (activated), glutaraldehyde gradually undergoes polymerization and loses it activity. At pH 7.5–8.5, polymerization is slowed down so that full antimicrobial activity is maintained.

| Table I. Opening pressures and mean resistances of the Heidbrink valves to different gas flow rates (range in parentheses) |
|---|---|---|---|---|
| Gas flow rate (litre min\(^{-1}\)) | Group I (6 valves) | Group II (10 valves) | Group III (5 valves) | Group IV (5 valves) |
| 10 | 0.50 (0.44–0.53) | 0.08 (0.05–0.11) | 0.12 (0.08–0.14) | 0.30 (0.23–0.35) |
| 20 | 0.62 (0.56–0.66) | 0.16 (0.13–0.19) | 0.21 (0.17–0.23) | 0.48 (0.41–0.53) |
| 30 | 0.78 (0.72–0.8) | 0.28 (0.25–0.29) | 0.28 (0.26–0.29) | 0.66 (0.57–0.75) |
| 40 | 0.86 (0.80–0.91) | 0.35 (0.32–0.39) | 0.36 (0.34–0.39) | 0.76 (0.64–0.83) |
| 50 | 0.95 (0.89–1.01) | 0.44 (0.40–0.51) | 0.45 (0.42–0.49) | 0.89 (0.79–0.95) |
| 60 | 1.18 (1.12–1.24) | 0.55 (0.52–0.6) | 0.58 (0.54–0.62) | 1.02 (0.90–1.08) |
| Opening pressure (kPa) | 0.56 (0.53–0.62) | 0.08 (0.05–0.12) | 0.10 (0.07–0.12) | 0.28 (0.22–0.32) |
Fig. 2. The inferior surface of a disc from a valve in group I under high magnification (S.E.M.). It shows pitting (a), cracking (b) and aggregated particles on the surface of the disc (c).

Fig. 3. Inferior surface of a disc from a valve in group III (S.E.M.). The surface of the disc appears to be intact and no foreign particles can be seen.

guide and will result in sticky surfaces. This will lead to stickiness and an increase in the opening pressure and resistance of the valves. It has been suggested by the manufacturers that this might result from improper rinsing of the valves following disinfection in Cidex solution. This might have been the case for the old valves (group I), but not for the valves in group IV, since the valves were rinsed meticulously. Presumably, the increased resistance to expiration does not lead to any clinical ill-effect. However, it is reasonable to suggest that such resistance should be controllable and valves used should have a low resistance which can be varied at will.

Glutaraldehyde is non-corrosive, and Cidex solution contains an anti-corrosive agent. However, the discs of the valves in group I showed marked corrosion and the discs in group IV showed early signs of corrosion. The components of the Heidbrink valves are made or plated with dissimilar metals which are in contact most of the time. It is reasonable to assume that the repeated and prolonged immersion of the valves in an electrolyte solution such as Cidex may lead to an electrolytic type of corrosion of the discs of the valves. Also, given time, the valves in group IV would be likely to develop a degree of corrosion similar to that in group I. Stark (1972)
stated that, where a cold sterilizing agent is chosen, glutaraldehyde "used strictly to the manufacturer's instructions is the agent of choice". Therefore, in order to reduce the risk of corrosion and to ensure total elimination of residual air from the valve for efficient disinfection and rinsing, complete dismantling of each Heidbrink valve is necessary. This would be time-consuming and could damage the components of the valve.

In group III stickiness was not a problem and increase in the opening pressure or resistance of the valves was small (table I). Furthermore, there was no corrosion in any valve disc.

These findings suggest that sterilization by autoclaving is more suitable and less harmful to the Heidbrink valves than is Cidex solution.

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REFERENCES


EFFETS ADVERSES DU GLUTARALDEHYDE TAMPON SUR LA SOUPAPE EXPIRATOIRE D'HEIDBRINK

RESUME
L'effet de la désinfection chimique de la soupape expiratoire d'Heidbrink dans du glutaraldéhyde tampon (solution de Cidex) a fait l'objet de recherches. Le Cidex provoque une certaine viscosité et fait augmenter la pression d'ouverture et la résistance de la soupape aux différents débits de gaz. Il peut aussi se produire un type électrolytique de corrosion. De toute façon, le passage à l'autoclave de la soupape d'Heidbrink ne semble pas entraîner de corrosion ou de modification appréciable de sa pression d'ouverture ou de sa résistance.

Se averiguó el efecto de la desinfección química de la válvula expiratoria de Heidbrink en glutaraldéhido tampón (solución Cidex). El Cidex causó una viscosidad y aumentó la presión y resistencia de apertura de la válvula en distintos ritmos de flujo del gas. También, puede haber ocurrido un tipo de corrosión electrolytica. Sin embargo, la esterilización en autoclave de la válvula de Heidbrink no parece haber causado alguna corrosión ni una alteración significativa de su presión o resistencia de apertura.