Foley Catheter Action in the Nasopharynx
A Cadaveric Study

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Objectives: To determine the action of the Foley catheter in the posterior nasal cavity in relation to balloon volume, and to deduce its implications in the treatment of posterior epistaxis.

Design: Human cadaveric study.

Materials: Twenty nasal fossae of 10 adult cadavers.

Interventions: A Foley catheter (size 14) was inserted into the nasopharynx via each nostril. The catheter balloon was inflated to its recommended maximum volume with 15 mL of water. Firm traction was applied to the catheter. Colored liquid was instilled into the ipsilateral aspect of the nasal cavity, and liquid leakage into the contralateral side was monitored using a nasoscope. The balloon was reduced in volume by 1-mL steps, and the same fluid infusion and documentation procedures were performed for each reduced volume until the balloon slipped out of the nose. The procedure was repeated in the opposite nostril.

Main Outcome Measures: Successful choanal sealing and anterior balloon shift into the nasal fossa in relation to the balloon size.

Results: The Foley catheter balloon sealed the choana without any leakage of infused liquid into the contralateral side at appropriate inflation volumes in 17 (85%) of 20 nasal fossae. Complete sealing between volumes of 12 and 15 mL was achieved in 13 fossae (65%), between 11 and 15 mL in 10 nasal fossae (50%), and between 5 and 15 mL in 3 nasal fossae (15%). Failure to seal at any volume occurred in 3 nasal fossae (15%). Bimodal seal (ie, complete seal at high [15 mL] and low volumes [4-7 mL], but leakage in intermediate volumes) occurred in 3 nasal fossae (15%). The balloon remained in the nasopharynx under traction and did not slip past the choanal rim to encroach on the middle and inferior turbinates until the balloon volume was reduced to between 4 and 7 mL. The balloon slid out of the nose at a volume of 5 mL or less. The inflation volumes ranging from 8 to 12 mL were statistically more effective in sealing the choana than lower volumes (4-7 mL) (P<.002, χ² test).

Conclusions: At different inflation volumes, the Foley catheter balloon acts primarily (1) as a platform for an anterior gauze pack (at 4-15 mL); (2) as an effective seal of the choana (at 8-15 mL usually and at 4-7 mL occasionally); and (3) as a compressor of the region behind the middle and inferior turbinates (at 4-7 mL), provided that the balloon under traction does not slip out of the nose.

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EPISTAXIS is a common clinical condition, with many effective treatment options. The most traditional and widely practiced treatment of the posterior type of epistaxis involves applying an inflated Foley catheter balloon into the nasopharynx in combination with an anterior gauze pack. The Foley catheter balloon insertion procedure is well described in medical textbooks.¹ A typical description includes a balloon inflation volume of 10 to 15 mL and the application of traction, which is maintained by sliding the catheter over a piece of plastic tubing, and the 2 tubes are then clamped together.

Several modes of action of the Foley catheter balloon in the treatment of posterior epistaxis have been discussed in these textbooks. For instance, in one mode of action, the inflated Foley catheter balloon may act as a stable platform in the nasopharynx for the insertion of an anterior gauze packing, which is solely responsible for arresting the epistaxis. In another mode of action, with effective traction applied to the catheter, the balloon may compress the bleeding vessels and prevent bleeding down the oropharynx. Although these theories, and others, provide plausible explanations for the action of the Foley balloon in the treatment of...
MATERIALS AND METHODS

We studied 20 nasal fossae in 10 (6 male and 4 female) adult cadavers (mean age, 70 years; age range, 25-90 years) at the mortuary of the Prince of Wales Hospital, Shatin, Hong Kong, from April 1999 to May 1999. The cadavers were selected according to the following criteria: each cadaver had to have been recruited within 24 hours of death, to maintain tissue elasticity; each had to have a normal nose and nasopharynx; and each had to have a nasal fossa that would allow the passage of a 4-mm 0° rigid nasoendoscope and a size 14 Foley catheter via the nostril.

The cadavers were placed in a supine position with the necks fully extended; then, the nasal fossae were thoroughly cleaned with water and suction dried. A Foley catheter was inserted along the floor of a nasal fossa to reach the nasopharynx, as it would during clinical practice; its location in the nasopharynx was confirmed by endoscopy. The catheter balloon was inflated with water to its recommended maximum volume (15 mL) using a 20-mL syringe. Gentle but firm traction was applied to the catheter by hand. While the balloon was under traction, the ipsilateral aspect of the nasal cavity was filled with colored liquid (diluted povidone-iodine [Betadine] solution with a watery consistency) via a syringe. A 0° nasoendoscope placed in the contralateral aspect of the nasal cavity was used to observe any leakage of the colored liquid. If no leakage occurred under traction, the traction was relaxed to determine if leakage would then occur.

The balloon volume was then reduced in 1-mL steps, and fluid infusion and documentation procedures were performed for each reduced volume until the balloon slipped out of the nose. We believed that withdrawing 1 mL of water from the balloon using the syringe each time would result in inaccurate volume measurement because the balloon was under pressure and some water loss could occur from the catheter injection port, or because slightly excessive water loss could occur during syringe connection or disconnection. To avoid these possibilities, the water was completely emptied and measured at the end of each test, and an accurate amount of volume was injected into the catheter in 1 shot through the catheter injection port.

Since repeated inflation and deflation of the balloon as required in this study could lead to balloon valve damage, we used a new catheter after a run of tests in 2 or 3 nasal fossae. When the catheter was used for the first time, it was always flushed with water and completely emptied of air trapped in the tubing and the deflated balloon.

The position and conformity of the balloon and the site of leakage of colored liquid in the posterior aspect of the nose were noted. Choanal sealing and anterior balloon shift into the nasal fossa were documented in relation to balloon size. Choanal sealing was always determined when the catheter was under traction. Choanal leak was also tested after the traction was released. The relationship of the balloon with the posterior ends of the turbinates was also recorded.

The tests were performed in both nasal fossae for each cadaver. χ² Tests were used to determine whether complete choanal sealing by the balloon at a higher range of inflation volumes is statistically more effective than at a lower range of inflation volumes. P<.05 was considered statistically significant.

RESULTS

Typically, 16 individual tests were performed on each nasal fossa, starting from a balloon volume of 15 mL, which was reduced by 1-mL steps. The entire experiment on a nasal fossa was completed when the balloon slipped out of the fossa under traction; this usually occurred when the balloon volume reached 3 or 4 mL.

The volume of water that was emptied from the balloon at the end of each test matched the original injected volume throughout the experiment. This procedure indicated that there was no loss of water from the balloon or the catheter injection port during the experimental procedure.

Our results showed that the Foley catheter balloon effectively sealed the choana without any leakage of infused colored liquid to the contralateral side at appropriate inflation volumes in 17 (85%) of 20 sides. A complete seal at any volume was achieved at 12 to 15 mL in 13 nasal fossae (65%), 11 to 15 mL in 10 nasal fossae (50%), and 5 to 15 mL in 3 nasal fossae (15%). In 3 nasal fossae (15%), a complete seal was only possible at maximal or near-maximal volume (14 or 15 mL). In 3 nasal fossae both nasal fossae in 1 cadaver and 1 nasal fossa in another), a complete seal was not possible at any inflation volume, with or without traction. Therefore, in our study, 15 mL was the only inflation volume that produced a complete seal in all but 3 nasal fossae (85%).

Bimodal seal (ie, a complete seal at high [15 mL] and low [4-7 mL] volumes, but leakage at intermediate volumes) occurred in 3 nasal fossae (15%). However, in all cases, whether bimodal or not, a low-volume seal was achieved with traction in 6 nasal fossae (30%). The seal that was achieved at lower volumes was probably attributable to the conformity of the less pressurized balloon being pulled against the choana and turbinates. Without traction on the catheter, leakage always occurred at these lower volumes; however, sometimes leakage did not occur at high volumes without traction, as the balloon was tight against the nasopharynx and the choana.

We studied the site of leakage when the catheter was under traction. If leakage occurred at high inflation volumes, it frequently took place in the crescentic gap formed by the edge of the dome of the choana and the inflated balloon. If leakage occurred at lower inflation volumes, it occurred from several sites, including the dome of the

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choana, around the eustachian cushions, and along the vomer.

At volumes of 10 to 15 mL, the balloon occluded both choanae and compressed both eustachian cushions (Figure 1 and Figure 2). Usually, at volumes of 8 to 9 mL, compression on the contralateral eustachian cushion became less prominent and the contralateral eustachian orifice was more visible.

The balloon remained in the nasopharynx, even under traction at volumes of 8 to 15 mL. When the volume was reduced to 7 mL, the balloon slipped forward on traction and impinged on the posterior end of inferior turbinate in only 6 nasal fossae (30%). This impingement occurred in 7 fossae (35%) when the balloon volume was 6 mL (Figure 3). At volumes of 4 to 5 mL, the balloon impinged on both ends of the middle and inferior turbinates in 16 nasal fossae (80%) (Figure 4). In summary, at volumes of 4 to 7 mL, the balloon could be pulled forward and slipped past the rigid rim of the choana to impinge on the ends of middle and inferior turbinates and occasionally sealed the choana. The balloon tended to slide out of the nose at volumes of 5 (4 fossae, 20%) and 4 (10 fossae, 50%) mL. The balloon always dislodged (100%) by traction at a volume of 3 mL. At volumes of 8 to 15 mL, the balloon remained in the nasopharynx and acted as an effective seal of the choana. These inflation volumes (8-15 mL) are significantly more effective in obtaining a complete nasopharyngeal seal than lower volumes (4-7 mL) ($P<.002$, left side; $P<.001$, right side). The behavior of the Foley catheter balloon at various inflation volumes under traction in all 10 cadavers is detailed in the Table.

**COMMENT**

The Foley catheter balloon has been used for the treatment of posterior epistaxis for more than 40 years. It is still frequently used for the initial management of the condition, as it is simple to apply and is readily available in hospitals. Previous studies on the use of the Foley cath-
eter for epistaxis focused on the effect of air- or water-filling characteristics of the balloon over time; ex vivo and spontaneous deflation of the balloon was found 24 hours after inflation with air.2,3 These studies confirmed that water was suitable for the inflation of the Foley balloon, and the volume injected into the elastic balloon remained undiminished, as no deflation occurred over time. In another study, other nasal balloons, such as the Brighton balloon, were used, and their appearance in the posterior aspect of the nose of cadavers was observed radiographically after the balloon was inflated with urografin.4 The study showed that the filled balloon tended to occupy the nasopharynx and compressed the skull base and the soft palate. To our knowledge, no studies have been performed to show the effects of various inflation volumes on balloon behavior or whether choanal sealing is achievable by balloon occlusion. The present study was designed to elucidate the correlation of different inflation volumes of water with respect to the effects on the Foley catheter balloon in human cadaver noses.

Clinically, occlusion of the posterior aspect of the nose with a Foley catheter balloon is known to be an effective treatment option in most cases of posterior epistaxis. However, failure to control epistaxis can still occur even if its cause is idiopathic, and further treatment may have to involve submucous resection of the septum, posterior packing with a roll of gauze, arterial ligation, or embolization. In bleeding diathesis, balloon occlusion alone is unlikely to be effective, and replacement therapy with appropriate clotting factors must also be implemented.

One of the causes of failure of treatment of posterior epistaxis with the Foley catheter is ineffective traction on the catheter; over the years, it has been recognized that ineffective traction can largely be overcome by adopting a simple counter-traction principle by which the catheter slides over an outer piece of plastic tubing, and the 2 tubes are then clamped together under tension.5 Other likely causes of failure, even with sufficient traction on the catheter, are failure to compress the bleeding point or its feeding vessel and failure to completely seal the choana with the balloon.

In clinical practice, when the Foley balloon in the nasopharynx is pulled onto the choana, it acts as a buttress against which an anterior pack may be tightly wedged. The textbook recommendation1 is to inflate it with 10 to 15 mL of water. To be an effective buttress, the balloon must remain stable in the nasopharynx during traction on the catheter. Our study showed that the inflated balloon, at volumes of 8 to 15 mL, remained stable in the nasopharynx despite traction. It started to slide forward past the choana to touch the inferior turbinate at volumes of 6 or 7 mL, and to touch the middle turbinate as well when the volume was reduced to 4 or 5 mL. In a small number of cases (15%), the balloon would become dislodged by traction at a 5-mL volume; this invariably happened when the volume was reduced to 3 mL. Therefore, we found that the balloon could remain in the nose at volumes of 6 to 15 mL, despite some forward shift at lower volumes. At these volumes in all cases, and at a lower 4- to 5-mL volume in a few cases, the balloon was able to act effectively as a buttress for an anterior nasal pack.
We also found that if the zone between the posterior ends of the inferior or middle turbinates and the choanal rim needed to be packed with gauze, the ideal balloon volume was between 8 and 15 mL, as the balloon remained in the nasopharynx at these volumes. If packing of this zone is desired when the size of the balloon is 6 to 7 mL, then strong traction of the catheter must be avoided during packing, or the zone will be occluded by the balloon, which will slip forward. When the size of the balloon is 6 to 7 mL, or even 4 to 5 mL, the balloon can be pulled into the zone to press on an anterior pack that has already been positioned there. This proposed procedure may enhance epistaxis control if the bleeding originates from this region (the sphenopalatine foramen, the sphenoidal recess, and the posterior ends of the turbinates). Reduction of the balloon to an appropriate volume can help compress a bleeding source in the posterior aspect of the nose, as long as the balloon does not become dislodged.

Our study showed not only that the Foley catheter acts as a buttress for an anterior pack at 1 range of balloon volumes (8-15 mL in all cases; 4-15 mL in many cases) as well as a potential compressor of the region between the choana and the posterior ends of the turbinates at another range of inflation volumes (6-7 mL in all cases; 4-7 mL in many cases), but that it also works as “stopper” for the choanal opening at high volumes, with effective sealing at 15 mL in 85% of cases and at 12 mL in 65% of cases. At lower inflation volumes (<12 mL), the rate of failure to seal progressively increases, and only occasionally (30% of cases) does a complete seal occur at low volumes (4-7 mL) with the aid of catheter traction. Failure to seal the choana completely may explain why, in a small number of clinical cases, posterior epistaxis cannot be controlled effectively despite the use of the Foley catheter. Clearly, higher volumes are more likely to produce a good choanal seal. Our study showed that inflation volumes of 8 to 12 mL were statistically more effective in sealing the choana than lower volumes (4-7 mL).

In the clinical setting, the physician must take into account the following factors before choosing an inflation volume: the effectiveness of arresting the epistaxis at a particular balloon volume; the effectiveness of maintaining anterior traction on the catheter; the discomfort experienced by the patients at high volumes; and the optimal distance that an anterior pack can be inserted posteriorly against the balloon. Although a wattertight choanal seal was achieved in our study when the balloon volume was 15 mL, the use of such a high volume may induce excessive pain and displacement of the soft palate if it is adopted clinically.

Based on our findings, and keeping the clinical considerations mentioned above in mind, we believe that there are 2 approaches to the clinical problem of posterior epistaxis using the Foley balloon. First, it is worth first trying an inflation volume of 12 mL of water, as this would potentially seal the choana in 65% of cases. The ipsilateral aspect of the nose should also be packed with ribbon gauze as far back as possible against the balloon surface. If there is no bleeding down the oropharynx and the patient is not in excessive distress, then the treatment is deemed effective, and the procedure is completed by securing the catheter traction as usual. If bleeding continues or if there is discomfort from excessive pressure, up to 6 mL of water (half the volume injected initially) can be withdrawn from the balloon, and further traction can then be applied to the catheter. This procedure would allow some anterior shift of the balloon, which will compress the gauze pack in the region between the choanal rim and the posterior ends of the turbinates and potentially help to constrict any bleeding source in that region. Second, lower balloon volumes that allow compression of the surface area between the choana and the turbinates (6-7 mL in all cases; 4-7 mL in many cases) can be tried first, as this procedure may also be effective in controlling posterior epistaxis with less discomfort. However, even with these 2 approaches, the Foley catheter may not be successful in dealing with bleeding originating from the arch of the choana, since this area is often a site of incomplete seal, even at high balloon volumes, as seen in this study. However, this kind of bleeding should be amenable to other forms of direct packing, such as a long, expansible, absorbent pack.

Our goal was not to advocate Foley catheter packing, as we fully recognize the armamentarium of options that are available for treating posterior epistaxis, particularly with the advent of endoscopic endonasal surgery. Our purpose was to elucidate the mechanisms by which the Foley catheter balloon acts in the posterior aspect of the nose and the choana. This cadaveric study was performed with accurate balloon volume measurements and documentation; therefore, it provides experimental evidence of Foley catheter action in the posterior aspect of the nose. It is unlikely that this form of experimentation can be repeated in patients who present with epistaxis or in subjects with biologically viable tissues. Nevertheless, our results may be useful as guidelines in clinical practice. We found that a Foley catheter balloon can often seal the choana effectively at high balloon volumes (8-12 mL), but that complete sealing is not always necessary, as other factors, such as clot formation adjacent to the balloon, may also produce an effective tamponade. However, tight sealing of the choana, as well as such mechanisms as compression of the posterior nasal area, which is achieved at lower balloon volumes, is likely to be an important mode of action of the Foley catheter in controlling posterior epistaxis.

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REFERENCES