Proffered review

Benign oesophageal strictures: historical and technical aspects of dilatation

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SUMMARY

A review of the different bougies used over the years confirms that the dilators presently available are adequate for the conservative management of oesophageal benign strictures. Most of these are of an old but well-tested design. Several additional techniques may have to be tried in difficult patients. Dysphagia can be relieved by the passage of size 39 FG bougies but many will wish to increase this to 60 FG, if it is possible. Failure of conservative management by dilatation only can be defined as (a) technical impossibility to dilate sufficiently to relieve the dysphagia, which is rare, or (b) when the patient or the surgeon considers the procedure is being done too frequently, which must be measured in FG for the bougie and weeks for frequency. The more expert the surgeon becomes at dilatation, the safer it will become, and the necessity for surgical intervention will be less frequent.

The history of treating benign oesophageal strictures demonstrates clearly that previous generations of doctors were both ingenious and versatile because success depended on their technological expertise. The majority of the instruments we use today are not new inventions, they are merely developments of their old original ideas using modern materials. Each patient with an oesophageal stricture is different and requires individual treatment. Consequently, it is essential to read descriptions by the old masters who managed all types of problems in order to learn forgotten techniques, which may be of use in difficult patients. This paper is concerned primarily with technology rather than the indications for dilatation and management of benign oesophageal strictures. An attempt will be made to describe those methods which have proved helpful over the years, with emphasis on measurement of the size of the dilators.

Historical review of techniques

Early days

Blind bougienage was used from the sixteenth century onwards. Fabricius ab Acquapendente (1537–1619) is cited as the first to use a wax taper with which he pushed a foreign body onwards into the stomach. The word bougie is derived from the Arabic town, Boujiyah, in Algeria, a medieval centre for the wax candle trade. Ambroise Paré (1510–1590) made tubes of leather or wands covered with gut, and, for less firmly impacted objects, quills made from swan feathers. Later, an instrument of lead with an olive-shaped tip utilizing gravity and the heavy weight were used to disimpact foreign bodies rather than relying on the push of a bougie. Willis (1621–1675), the famous anatomist whose book was illustrated by Christopher Wren, was the first to describe dilatation for achalasia and used a whalebone probang with a sponge on the end (1). The whalebone was taken from the large filter in the mouth of the whale. Long strips were flexible and could be machined like a modern plastic so were useful for corsets or pushing down the gullet because they had the correct combination of rigidity and flexibility. Most of the blind bougienage performed at this time was done for foreign body impaction, but caustic strictures due to swallowing lye or sulphuric acid were also treated by blind dilatation and the technique was well established by the early nineteenth century (2).

Late nineteenth century

Oesophagoscopy was developed in the second half of the nineteenth century. The instruments were based on those used for laryngeal inspection and, since ENT surgeons were still general surgeons, the technology was a mixture of that already invented for looking into the throat and the bladder. Semelder and Stoerk in 1866 made an extensible tube for a brief look at the upper oesophagus based on a laryngeal mirror type of examination (3). Stoerk's oesophagoscope of 1881 (4) was a purpose-built rigid tube for looking further down the gullet, but Kussmaul in 1868 was probably the first surgeon actually to see anything in the lower oesophagus (5). Kussmaul passed a hollow tube developed from Desormeaux's cystoscope down the gullet of a professional sword swallower but even he admitted that with proximal illumination the view was poor and obscured by refluxed fluid. Mikulicz in 1881 developed an oesophagoscope with distal illumination and it can be presumed that he was the first actually to see the whole of the oesophagus properly (6). Prior to this, all views were for 10–15 seconds only, with poor illumination provided proximally, obviously no bougienage, biopsies or instrumentation were possible during the early oesophagogastroscope (7–9).

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Early twentieth century

The application of X-rays to the diagnosis of oesophageal diseases proceeded fast after Roentgen's discovery in 1895. The following year, Downie (10) used the technique to demonstrate a foreign body. The heavy metal bismuth was first used by Holzknecht in 1900 (11) and barium came later. The first oesophageal stricture demonstrated radiologically was described by Dawson in 1907 (12).

Chevalier Jackson visited Morell Mackenzie in London towards the end of the nineteenth century and took back with him to the United States the latest technology from Europe, because Mackenzie himself had close contact with the German-speaking surgeons. It was Chevalier Jackson who developed practical instruments rather than just looking down the rigid oesophagoscope. He designed bougies, biopsy instruments and above all made the extraction of foreign bodies a safe procedure. Benign oesophageal strictures were dilated but, apart from diagnosis, nothing could be done with malignant tumours at this time. Chevalier Jackson was the first surgeon to be allowed by his colleagues to call himself a specialist in otorhinolaryngology and this later developed into a special school of medicine rather than just looking down the rigid oesophagoscope. If the patient uses self-bougienage or passed without anaesthetic, it is obviously more comfortable to have the same diameter throughout and a wire is uncomfortable in the back of the throat. The length of the dilating part of the bougie is 7 cm in Chevalier Jackson's bougies, 5 cm in Souttar's original aluminium dilators (Fig. 7) and 4 cm in the Eder-Puestow dilators (Fig. 8). By experience, anything between 4 and 7 cm length is practical. It is essential for the proximal end to be well rounded so that it will not be caught on the edge of the oesophagoscope on withdrawal.

Bougies

The two most widely used oesophageal bougies are the Chevalier Jackson type with a wire shaft (Fig. 1) and the graduated rods with blunt ends (Fig. 2). Both are made of gum elastic over a woven base. There have been many designs for bougies (Fig. 3). The shape of the end is usually tapered like that of the original wax bougies or tapers, the catalogue description of which is conical. The gum elastic bougies of woven material have a rounded end consisting of half a sphere.

Mention has already been made of the original wax bougies and whalebone probangs, which provided the essential qualities of rigidity with flexibility and the ability to hold a curve for insertion into the oesophagus. Latex rubber usually proved to be too soft, although used since 1881 for feeding (13) and 1910 for gastric aspiration during paralytic ileus (16). Gum elastic is an old material which had many ideal properties. There is only one factory in the world now...
making gum elastic bougies, Eschmann's at Lancing. Numerous coats of a vegetable-based oil are applied over a shaped mould of woven silk, which harden by oxidation of the oil in a drying cupboard. Flexibility occurs without cracking and this can be increased within certain limits by warming to body temperature, but softening occurs with age. Sterilization is a problem because obviously they melt with boiling or autoclaving. The majority of such bougies in the hospitals of England must be over 30 years old with a similar vintage for the Negus oesophagoscope through which they are passed.

Flexibility and the ability to hold a curve is an essential property of gum elastic which is hard to obtain from other materials. One method of avoiding the need for this material is to decrease the length of the dilating portion and to replace the flexible part with a coiled wire spring such as is found in the Eder-Puestow dilators (Fig. 8). Another way is to use Teflon, the trade name for polytetrafluoroethylene (PTFE), which is an almost perfect material (17). It was discovered in 1938, copied in 1946, and is sold in Europe. It is used in the mercury-filled bougie, the earliest of its type (18-20). It can be autoclaved without change in structure, its surface tension is so low that no lubricating jelly is needed; in small diameters it can bend and hold its shape with rubber with a blue disadvantage, because of its high melting point, is that it cannot be easily moulded into shape but this does not matter with bougies since they can be easily machined on a lathe from the solid material.

Size

There has been much confusion because measurement of bougie size has not been standardized. English channel gauge (EG) was widely used originally, not only in Great Britain but also in the United States, and there was reference in the early German literature to it. EG is actually metric and based on the diameter in millimetres with 0-5-mm increments, but because a catheter with a diameter of 1 mm is designated EGO, conversion to mm diameter necessitates the EG number being divided by 2 and adding 1. This simple arithmetic seems to have confused the mainland of Europe. It would have been easier for us all to remain with a system based on the diameter measured in mm but French gauge (FG), based on the circumference, has been almost universally adopted. Charrière, a Parisian instrument maker (1803-1876), used FG for his catheters and this indicates the circumference in millimetres. Conversion to mm diameter is obtained by dividing with \( \pi \) or more simply by 3.

In the smaller-sized bougies this simplified conversion factor does not matter too much but at the larger size of FG 75, the diameter is 25 mm when \( \pi \) is 3 and 23-9 mm when \( \pi \) is 3-142. Gum elastic catheters have never been made to an engineering degree of accuracy because it is difficult to achieve this with the available techniques. In fact, the manufacturing standards for rubber catheters accept plus or minus one unit of FG, \( \pm 0-03 \) mm diameter, for any given size.

Bougies are usually available in graduated sizes from 9 FG (3 mm in diameter) to 39 FG (13 mm in diameter). Half an inch diameter is the Imperial equivalent of 39 FG, which explains why this is a much quoted optimum size. Some of the woven gum elastic bougies go up to 45 FG and the Eder-Puestow dilators are sold with graduated olives to 45 FG. However, greater sizes are occasionally needed if large indwelling palliative tubes have to be inserted, and the manufacturers can provide additional olives to 58 FG.

Mercury-filled bougies

The concept of using a weighted bougie was first used in the eighteenth century and termed Bleihammer by the Germans because they were made of lead. The same principle is used in the mercury-filled bougie, the first described by Sir Arthur Hurst in 1915 (21) and extensively developed by him for the treatment of achalasia. Hurst’s mercury-filled bougies are made of rubber with a blunt rounded end (Fig. 9). Maloney’s bougies (22) are similar but with a tapered end (Fig. 9c) and a maximum diameter of 60 FG (more widely used in the United States). Both types are still available commercially. Most of the older sets in the country have disappeared because they were ‘attractive items’ to those who know the value of mercury. Manufacturers emphasize the short life of the rubber, but deterioration does not necessarily occur if rubber bougies are protected from sunlight and washed carefully after use. Their great advantage is with self bougienage and the difficult stricture in a kyphotic patient. Hurst originally thought that ideally each should weigh 1 lb 4 oz (567 g) and they are usually 75 cm long with diameters ranging from 12 to 45 FG. Obviously the weight, length and size can be altered to suit the individual patient.

Achalasia

Dilatation in achalasia is a special problem because the aim is to weaken the gastro-oesophageal sphincter so that the oesophagus can empty by gravity with aid from the small increase in intra-oesophageal pressure that results from the simultaneous contractions following each swallow. The lower sphincter can only be weakened if it is dilated widely. The normal rigid oesophagoscope has an external diameter of 60 FG. The usual limitation of the size of an oesophagoscope is the entrance to the oesophagus, the narrow slit of the esophagogastric sphincter. This is why the external diameter of a rigid scope is 60 FG or 2 cm in diameter. The upper sphincter has been measured on many occasions and Morell Mackenzie (23) gave the diameters as 25 x 14 mm. However, an oesophagoscope with a circumference of 75 FG (23-9 mm diameter) can pass through the upper sphincter of the majority of people. Experience has shown in achalasia that dilatation with mercury-filled bougies to 41 FG (24) or 60 FG (25) only gives temporary relief. This is because weakening of the lower sphincter by tearing the circular muscle fibres must be achieved with larger diameters. Dilatation in achalasia must therefore be to a diameter larger than the esophagogastric sphincter so that the
Majority of techniques depend on a balloon or mechanical dilator which can be expanded once it has been passing a gum elastic bougie every 10 days for the in 1898 was the first to develop a balloon filled with air for dilatation of achalasia (26). Plummer in 1906 (Fig. 10) used water in the balloon (27,28). Other balloons filled with air or water have been described by Sippy (29), Einhorn (30), Tucker (31), Mosher (32), Brouse and McHardy (33), Negus (Fig. 11), Thompson and Negus (34) and Boros (35). The other technique, using an expanding metal dilator (Fig. 12), was first developed by Einhorn in 1888 (36), but the instrument most used is that described by Starck in 1924 (37).

The authors consider 3-5 cm diameter or 105 FG as ideal. A larger diameter of 5 cm is probably too large and dangerous because of the risk of rupture and this is confirmed by de Rezende, a physician from Goiania, Brazil (personal communication, 1978) with a large experience of megaoesophagus in Chagas’ disease. In a recent article by Vantrappen and Hellemans, who use balloons of different sizes, the diameters recommended range from 3 to 5 cm (38), but their technique uses a progressive increase in size of the balloon on subsequent days and they only rarely dilate to 5 cm diameter. The subject has been recently very well reviewed with an assessment of the results from different techniques by Bennett (39). Full historical details are contained in Ellis and Olsen’s excellent monograph on achalasia (40).

Self-bougienage
Every surgeon interested in oesophageal strictures will have eventually at least one patient who is willing to do the oesophageal dilatation himself by self-bougienage. The author has one patient with a benign stricture originally under the care of Sir Henry Souttar, who has been passing a gum elastic bougie every 10 days for the past 30 years, and another with achalasia, originally operated on by Mr Hermon Taylor, who first used a mercury-filled Hurst bougie in 1935. Some require local anaesthesia, others can do it without.

Retrograde dilatation
Gastrostomy has been performed for dysphagia from very early days in an attempt to dilate the stricture from below. This is usually easier than from above because the entrance is funnel shaped and there is less chance of perforation. Schede suggested it in 1883, but Trendelenburg was probably the first to perform the operation, although others may have done it in the same year (41). By 1895, there were 28 patients in the literature who had been treated by retrograde dilatation (42). Mikulicz in 1904 developed the technique for achalasia (43). Instruments like Hegar’s intra-uterine dilators are the usual bougies for increasing the diameter from below (44). This technique is extremely valuable for treating young children with lye strictures. Often, the gastrostomy is left open so that either a continuous thread can be left in situ or small bougies with a loop on the end can be picked up through the stomach opening.

Continuous thread
Many of the patients with a gastrostomy were children who had swallowed lye, developed a caustic stricture and had total dysphagia. It was not surprising that techniques were developed for making future dilatations safer. Abbe in 1893 (45), followed by von Hacker in 1894 (46), was the first to develop the method of a guiding thread which was passed from the mouth through the stricture and then picked up out of the gastrostomy. Using it as a guide, dilators could be passed downwards or upwards. The term ‘bowstring’ was also applied to this technique. If the thread was drawn backwards and forwards with a sawing motion, the stricture could be cut or widened, and this technique was perfected by Dunham (Fig. 13) in 1903 (47), although Abbe had also used it. Dunham gave details of passing the thread down through the stricture so that it was sucked into the middle of the stream of water and picked up through the gastrostomy. Ochsner (48) was the first in 1903 to use thread as a guide without a gastrostomy, distal fixation being achieved by passage onwards into the small intestine. The technique was also used by others, including Plummer (49) and Tucker (50) (Fig. 14). In some, piano wire replaced the thread or twisted Chinese silk but it is obviously more difficult to swallow. The method has been developed further by the Eder Co. of Chicago for Puestow (51, 52) and the Eder-Puestow dilator system is available nowadays in the United Kingdom.
The Mayo Clinic technique (49, 53) with thread requires the patient to swallow it slowly over a period of 48 hours, never allowing the thread to become too slack as it goes down. This is still used nowadays and is an extremely safe technique. New materials for the guidewire principle in caustic strictures include a Silastic tube (54) and a Teflon-coated arterial guidewire (55). It is of special use in children (56).

Cutting and diathermy of strictures
Maisonneue was the first to describe an oesphago-tome in 1861 (57). This was done blindly for an oesophageal stricture and the technique was clearly developed from the urethrotome used for the much more frequent urethral stricture which did not respond well to dilatation. Jaap in 1873 devised an oesphagotome (58). The procedure was not without danger; it is much safer if done through an oesophagoscope (59) but has never really been much favoured.

Diathermy was available to the early laryngologists, cautery being first used in the oesophagus in 1847 (60), and is described in detail in Morell Mackenzie’s book of 1884 (23) mainly for the upper oesophagus. Diathermy incision of a stricture was described as early as 1900 (61) and recently using the flexible fibreoptic instrument (62). It is the basis of Dohlmann’s treatment of a pharyngeal pouch where the spur of the crico-pharyngeal muscle is diathermied through to provide a common cavity (63, 64).

Gradual dilatation
The principle that an indwelling tube might gradually dilate a stricture has been known since Blandin suggested leaving a bougie in place after dilatation in 1847 (65) and since Krishaber first passed a nasogastric tube through an oesophageal tumour in 1879 (15). It must be emphasized, however, that a nasogastric tube in a normal oesophagus can lead to a benign stricture due to reflux (66) if it is passed all the way into the stomach and left there for weeks. Mikeluz used shorter tubes ending above the gastro-oesophageal sphincter for postoperative feeding before 1900 (66, 43) and avoided the dangers of reflux. Morell Mackenzie described in 1884 how indwelling tubes could be fixed in the lumen of the oesophagus by tying strings to the ears or even in one curious instance to the moustache (23). The ability of an originally tight fitting tube eventually to become loose was turned to good advantage by Harvey and Negus in 1953 (67). They deliberately placed a metal bobbin with a central hole into a stricture anticipating its passing because of its shape and lack of a lip (Fig. 15). They used the descriptive word mole. The same technique was used by Gray in caustic strictures and his mole was made of acrylic with a stainless steel marker (68). The sizes were 20-30 mm in length, 10.5-16.00 mm outside diameter and a lumen of 3.5-5.0 mm. Other methods for gradual expansion have included tapered laminaria (69), the Didcott dilator (70), which is used in malignant strictures, and graduated plastic bougies (71).

Another ingenious idea was to use small balls for dilatation. They would become impacted and then either eventually pass through the stricture or have to be pushed by a bougie 1 day later. Abercrombie, a Scottish physician, was the first to suggest this in 1830 and von Hacker later developed it by using graduated metal balls with a diameter of 2-7 mm (61).

Permanent indwelling tubes
Most of the tubes used for palliative intubation of malignant strictures have also been placed in benign strictures. Apart from the usual problems that the tubes may be dislodged proximally or distally, there is the additional factor that they must be expected to stay there longer than with cancerous strictures. This means that rubber tubes of the Celestin type must be changed or at least checked every 6 months. Other materials do not have this disadvantage. Additionally, there is the danger of reflux above the tube in the oesophagus (72) producing an even worse oesophagitis than that originally experienced. These should be used only as a last resort in very old patients unfit for surgery who have to be dilated too frequently. It is essential for the tubes to be short and with a wide lip proximally.

Temporary indwelling tubes
If a tube is left in the oesophagus, whether of the short or long type passing out through the nose or a gastrostomy, the stricture tends to soften using the same principle as in gradual dilatation. Another use of the indwelling tube is during the acute phase of a corrosive burn of the oesophagus. One school considers that such a tube will prevent the opposing walls sticking together, will reduce the incidence of subsequent cicatricial stenoses and is an essential adjunct to treatment with antibiotics and cortisone (73).

Oesophageal dilatation
What size?
There is scanty information about the diameter of an oesophageal stricture that will cause dysphagia and just as little about the optimal diameter to which it should be dilated. There is an equal lack of measurement with regard to the symptoms of dysphagia because there is no accepted grading for difficulty in swallowing. However, a group of British oesophageal surgeons recently agreed to the following grades:

- 0 Normal
- 1 Occasional difficulty swallowing solids
- 2 Unable to swallow solid food
- 3 Unable to swallow minced food
- 4 Unable to swallow pureed or liquidized food
- 5 Unable to swallow liquids or saliva

The main reason why there is no definite diameter at which a certain dysphagia will occur must depend on local factors in the oesophagus as well as the threshold that each individual has before seeking medical advice.

It is the authors’ experience that patients presenting with a stricture may have a narrowing anywhere between 3 and 15 mm in diameter. Some will hardly admit the smallest 9 FG dilator, others obtain relief from the passage of a rigid oesophagoscope with an outside diameter of 60 FG which can be passed with little resistance. The average length of time with symptoms before diagnosis of an oesophageal cancer is 6 months.
months, many patients suffering more than they should. It cannot be emphasized too greatly that patients should consult a doctor when they have dysphagia before changing their eating habits.

The presence of blood is probably irrelevant and not necessarily a contraindication to further dilatation. A stricture should never be forcibly stretched so the grip of one or two fingers is a useful limit to the strength needed. Palmer dilates every day if necessary in order to achieve an adequate lumen (74, 75). There is no doubt that safety is gained by proceeding slowly and if there is any uncertainty the surgeon should stop. An indwelling nasogastric tube may make the procedure easier on the following occasion. Another suggestion is to leave the bougies down the oesophagus for a few hours after dilatation (76).

The key question is what is the optimum diameter required? In most instances the passage of a rigid scope will ensure dilatation to 60 FG (Negus and Earlam oesophagoscopes), but this is not always essential to obtain adequate or sufficient relief in any given individual. Chevalier Jackson bougies go up to 39 FG (0-5 in or 12-4 mm diameter if n equals 3-142), but many people will have adequate relief at 30 FG. Others suggest that dysphagia only disappears with dilatation of 41-45 FG (77). Each individual must be calibrated to his optimum diameter if the largest 60 FG cannot be achieved easily. Undoubtedly the muscular power in the oesophagus can be increased by practice and the best form of dilatation is continued swallowing. Manometrically, most patients with benign strictures have simultaneous low pressure contraction waves in the lower oesophagus. These may or may not be associated with oesophagitis. When a benign stricture is treated by partial gastrectomy and the stricture and oesophagitis revert to normal, weak pressure waves are often found in the lower oesophagus, so this may be an inherent abnormality in oesophageal strictures and not just due to oesophagitis. Each stricture has its own individual property and must be treated as a separate entity. It is the authors' practice not to attempt to achieve perfection by dilating to 60 FG if the patient is satisfied with a smaller than expected diameter.

**How frequently?**

Dilatation should be performed as frequently as is necessary to achieve adequate symptomatic relief. In many instances one dilatation alone with a rigid oesophagoscope is enough. It is almost impossible on the first occasion to predict which stricture will require further dilatation, with the proviso that the 3 mm ones will always be difficult. There is no definite information to suggest that regular dilatation is essential in the absence of symptoms. The alternative preferred principle is to repeat the dilatation as soon as dysphagia worsens in an attempt to persuade the patients to return prior to a change in their diet (78). On this basis, it is easier to establish a definition for failure of conservative management. This must then refer either to (a) the impossibility or failure to dilate adequately to relieve dysphagia or (b) when the patient or surgeon considers that the procedure is being performed too frequently. Conservative attitudes to the management of strictures have been suggested in many papers and books (79-83). There are other schools which either rarely perform any dilatation at all or do not recommend it prior to surgery (84, 85). Only by adequate measurement of the size and frequency of the dilatations can the correct answer be obtained for the balance between conservative management with dilatation and surgery, which should preferably be performed by the same individual (86-89).

**Conclusion**

This paper is concerned with technology and the history of the development of instruments used for dilating benign oesophageal strictures. The main question is whether there are enough satisfactory tools for doing the job or whether more should be invented because, if the technology is adequate, the doctor has only to perfect his technique. It is the authors' opinion that there are enough suitable instruments available and that surgeons especially interested in treating oesophageal strictures should have the following available, all obtainable from manufacturers in England:

1. Chevalier Jackson gum elastic bougies: sizes 9-39 FG. Fortunately still manufactured by Eschmann's, Peter Road, Lancing, St Leonards-on-Sea, West Sussex.

2. Gum elastic rod bougies: sizes 9-45 FG, unfortunately no longer manufactured by Eschmann's.

3. Teflon end and wire shaft bougies: sizes 9-54 FG. Size 39 FG is the maximum that will pass through the lumen of Earlam's small oesophagoscope and 54 FG the maximum for the larger oesophagoscope lumen. Manufactured by Seward's, Univac House, Blackfriars, London.

4. Eder-Puestow dilators and wire guide: sizes 21-45 FG. Any engineering department can make larger dilators from stainless steel or Teflon, but also available 48-58 FG from Keymed, Stock Road, Southend-on-Sea.


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**British Journal of Surgery Cover**

With the January 1982 issue, the size and format of the British Journal of Surgery will change. This is to allow the printers to introduce a more efficient typesetting process and to improve layout. The Editorial Committee has decided that at this time it would be appropriate also to change the general format of the Journal and, in particular, to alter the cover which has remained the same for many years. Therefore, from the first issue of 1982, the Journal will carry a picture on its cover which will change every month. During the first year, graphics of hospitals in the United Kingdom and Ireland will be presented.

The Editorial Board has been very fortunate in being able to commission Mr Albany Wiseman to draw the pictures for the first twelve issues. It is hoped that, at a later date and depending on demand, a limited edition of these graphics will be published by the British Journal of Surgery Society Ltd.