Techniques for Ensuring the Correct Length of New Mitral Chords

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Repair of degenerative mitral insufficiency has extensively been shown to be superior to replacement. In the majority of cases, the culprit lesion is limited to the posterior mitral leaflet (PML), which is treated with quadrangular resection of the prolapsing PML, annular plication of the corresponding segment of the annulus, and prosthetic annuloplasty. Anterior mitral leaflet (AML) prolapse is less common and is not always considered an indication for repair despite availability of a variety of surgical maneuvers specifically designed for its treatment. Although reliable if properly performed, chordal shortening at the papillary muscle level is technically demanding. Chordal transfer from the PML with the 'flip-over' technique is highly reproducible, but limited by the very frequent presence of an abnormal PML. Although feasible, transfer of an anterior basal chord to the prolapsing free edge assumes that the basal chords can be sectioned with impunity. More recently, chord replacement with expanded polytetrafluoroethylene (PTFE) sutures has become increasingly popular because of its availability, theoretical simplicity, and demonstrated long-term durability. Although papillary and leaflet anchoring of the neo-chord has not been shown to be a problem, the determination of its appropriate length remains intuitive and based on personal experience. Here, simple surgical maneuvers designed to ensure safe and reproducible results of single or multiple chord replacement with PTFE sutures are described.

The Journal of Heart Valve Disease 2003;12:156-161

The repair of degenerative mitral insufficiency has been shown in many cases to be superior to replacement. In most situations, the culprit lesion is limited to the posterior mitral leaflet (PML), which is treated with quadrangular resection of the prolapsing PML, annular plication of the corresponding segment of the annulus, and prosthetic annuloplasty. Anterior mitral leaflet (AML) prolapse is less common and is not always considered an indication for repair, despite several surgical maneuvers being available for its treatment (1). Although reliable if performed correctly, chordal shortening at the papillary muscle level is technically demanding. Chordal transfer from the PML with the 'flip-over' technique (2) is highly reproducible, but limited by the frequent presence of an abnormal PML. Although feasible, transfer of an anterior basal chord to the prolapsing free edge (3) assumes that the basal chords can be sectioned with impunity (4). More recently, chord replacement with expanded polytetrafluoroethylene (PTFE) sutures (5) has become very popular because of its availability and theoretical simplicity; moreover, this approach has shown long-term durability (6). Although papillary and leaflet anchoring of the neo-chord is not problematic, the determination of its appropriate length remains intuitive and based on personal experience. Herein, simple surgical maneuvers designed to ensure safe and reproducible results of single or multiple chord replacement with PTFE sutures are described.

Surgical techniques

Selection of the appropriate technique depends on two factors: (i) the presence or absence of a normal leaflet segment opposite the prolapsing segment; and (ii) whether single or multiple neo-chords are required. In all cases, in order to obtain the best possible visibility of the papillary muscles, the anchoring of the neo-chord is preferably carried out immediately after all leaflet incisions and resections have been performed, for example PML quadrangular resection, sliding incisions, or AML resections. Reconstruction of these inci-

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sions - and certainly the annuloplasty - should be carried out *after* the neo-chord has been secured to the papillary muscle. Placement of a neo-chord after annuloplasty is difficult because of the limited visibility of the papillary muscles.

Neo-chord with reference point present (Fig. 1)

Replacement of elongated or ruptured anterior (or posterior) leaflet chords (Fig.1) is very safe and simple when the opposite leaflet segment is normal. In this case, the normal segment of the PML provides a refer-

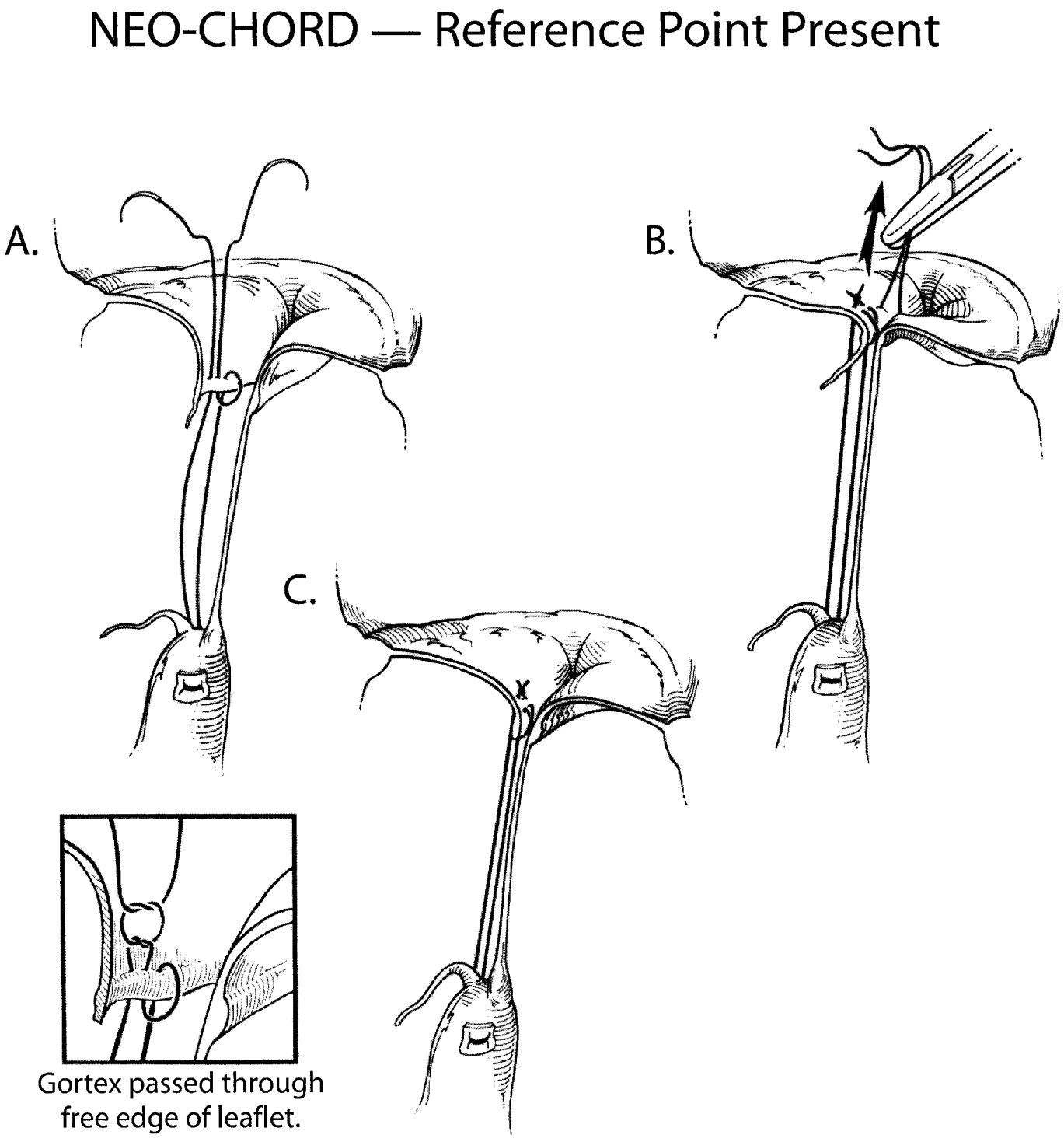

Figure 1: Placement of a single neo-chord in the presence of a non-prolapsing opposite leaflet, which is used as reference point.

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ence point, because the neo-chord should have the same length as the normal marginal chords of the opposing leaflet. A double-armed 5-0 PTFE suture (Gore and Associates Inc., Elkton, MD, USA) is passed through a small pledget and the papillary muscle head corresponding to the diseased leaflet segment. The two arms of the suture are then passed through the leaflet's free edge from its ventricular aspect toward its atrial surface. Normally, both arms are passed at about 2-3 mm from the free edge, and one of them is passed again through the ventricular aspect of the edge to maintain it bent toward the ventricle (Fig. 1A and insert). Both arms of the suture are not tied; they are kept aside with a mosquito. Next, a temporary 4-0 polypropylene suture is passed through the free edge of both the anterior and posterior leaflets close to the location of the neo-chord. An assistant pulls this temporary suture upward while the surgeon ties the PTFE suture (Fig. 1B). The normal marginal chords of the normal leaflet will determine the excursion of the flail leaflet segment and, therefore, the correct length of the neo-chord. The temporary suture is then removed (Fig. 1C). Because of the slippery characteristic of PTFE and the lack of an anchoring tissue, the natural tendency of the surgeon is to overcorrect the lesion. Also, the knots of PTFE tend to become undone; therefore, we recommend tying two to three loose knots at the right level followed by six to seven knots while the assistant holds the initial knots with forceps.

Neo-chord without reference point (Fig. 2).

In the absence of a reference point secondary to bileaflet pathology, the above technique cannot be used. The anchoring of the 5-0 PTFE to the papillary muscle and leaflet's free edge is similar to the previous case. The neo-chord must be maintained untied while all the repair maneuvers are being completed, including the placement of the annuloplasty ring. The neo-chord is then tied at the *level of the plane* of the annuloplasty ring. The surgeon should ignore the location of the free edge of the diseased leaflet, concentrating only on placing the initial loose knots at ring level. As in the previous case, the assistant should hold these knots with forceps while the surgeon properly ties the remaining knots. Experience has shown that most failures of neo-chord implantation are due to overcorrection, resulting in too short neo-chords that tether the leaflet downward. There is an apparent contradiction between tying the knots at the plane of the ring and the well-known fact that the coaptation point is well below the plane of the annulus. Besides finding this technique reliable through trial and error, recent data provide a possible explanation. Varnous and associates (7) reported that implantation of a ring automatically reduces the aortomitral angle, the AML/annulus angle, and excursion of the AML. These findings probably explain why moderate degrees of AML prolapse can be ignored and solved solely by annuloplasty.

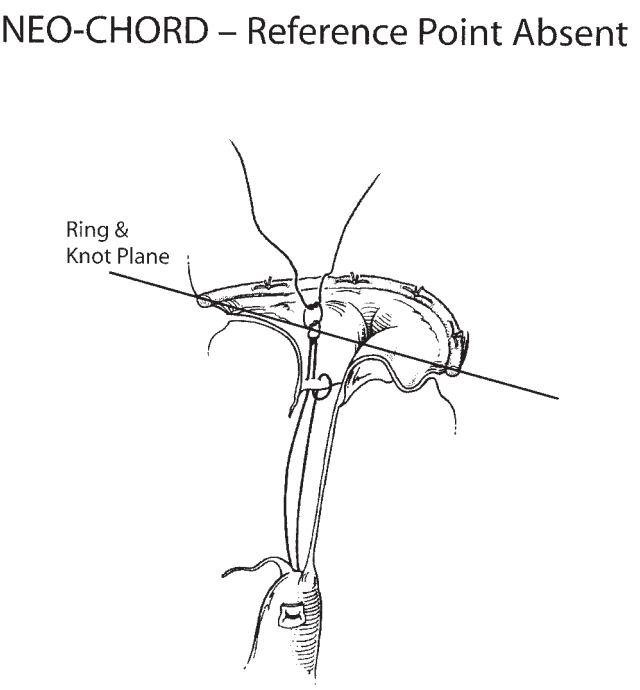

Figure 2: Placement of a neo-chord in the absence of a reference point.

Neo-papillary muscle (Fig. 3).

This technique is indicated in cases where most areas of the mitral valve show prolapse of very redundant leaflets. This so-called 'universal' Barlow's disease is most often considered beyond repair. A number of maneuvers besides placement of neo-chords, such as anterior and posterior leaflet resection and leaflet height reduction, must be performed (1). To ascertain an excellent view of the papillary muscles through a wide-open mitral orifice, the anchoring of the neo-chords to the papillary muscle(s) must be performed *after* all leaflet incisions and resections have been performed but *before* they are reconstructed (in all cases). In these cases, it is difficult to predetermine the number of neo-chords that will be necessary to achieve valve competence. It is also close to impossible to place further neo-chords after the annuloplasty ring is in place because of the limited visibility of a papillary muscle already crowded with other new chords. A solution to this problem is the use of a 'neo-papillary loop' or sling that will allow for the easy placement of several neo-chords even when the annuloplasty ring is in place. A double-armed 2-0 PTFE is used to construct a 4-5 mm loop at its midpoint (Fig. 3A). Both arms of the loop are passed through a pledget and the papil-

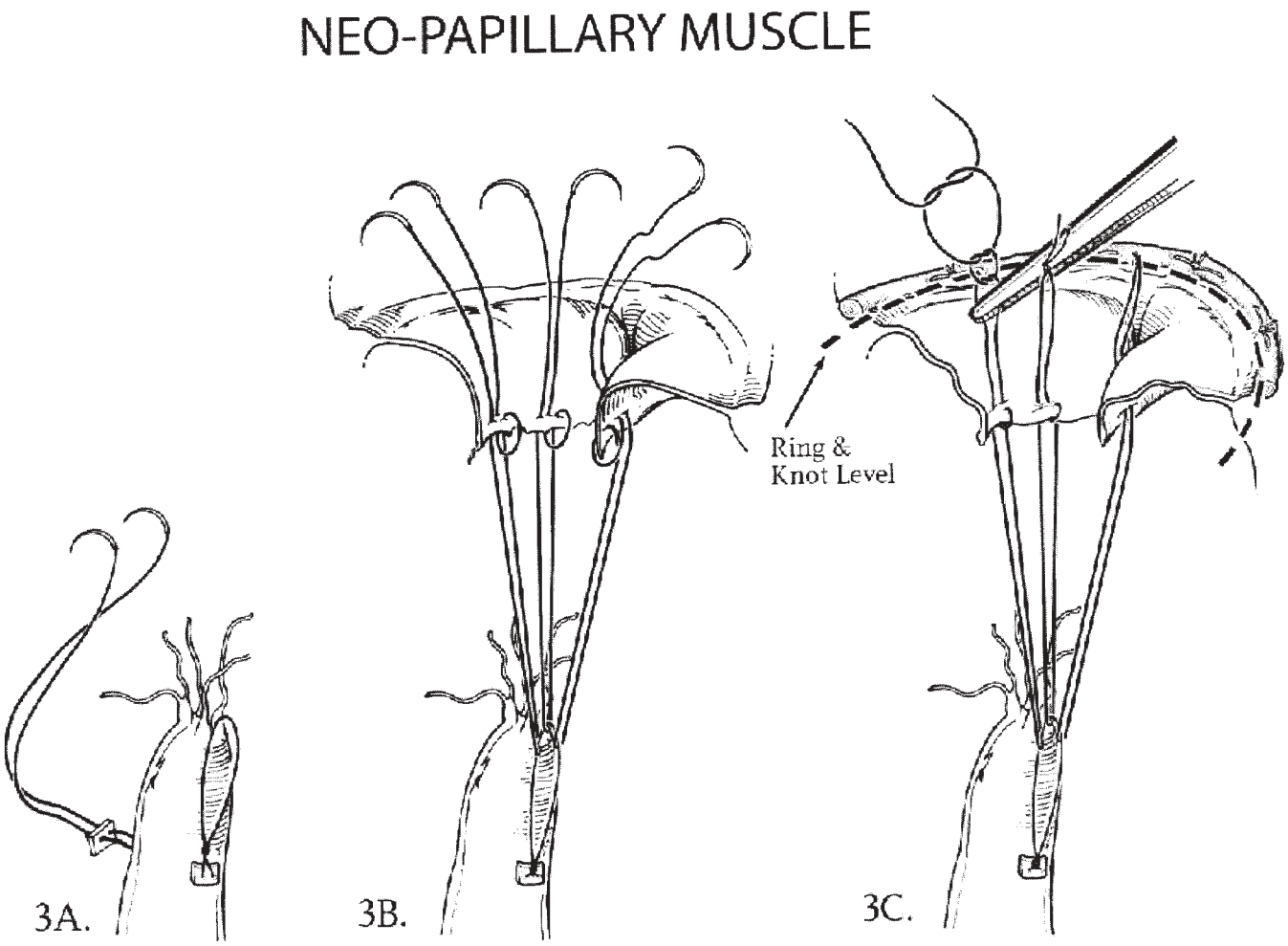

Figure 3: Use of the neo-papillary loop for the placement of multiple neo-chords.

lary muscle body at such a level that the upper top of the loop corresponds to the tip of the papillary muscle. The PTFE suture is then tied over another pledget. The loop should be located on the medial aspect of the papillary muscle so as to simplify its location when the neo-chords are passed through the loops. According to whether the prolapse is limited to chords arising from one papillary muscle or from both, one or two neo-papillary loops are placed. Although not essential, a 5-0 PTFE suture can be passed through the neo-papillary loop and kept with a mosquito so that the loop is easily found through a mitral orifice with an annuloplasty prosthesis.

After all repair maneuvers have been completed (including the annuloplasty), the 5-0 PTFE suture is passed within the annuloplasty ring and through the free edge of the leaflet. All other neo-chords that are necessary to achieve valve competence are then easily passed through the loop and leaflet free edge (Fig. 3B). In general, four neo-chords are sufficient to support the whole anterior leaflet. In these cases, it is difficult to assess the correct length of the neo-chords because of the lack of reference points. Attempting to determine where to tie the PTFE suture by observing the position of the leaflet's free edge while the ventricle is filled with fluid is unreliable. Although the experienced surgeon is regularly successful, there is a need for a reliable method that will immediately increase the rate of repairs across the spectrum of surgical expertise. It was observed that the most common error was overcorrection due to: (i) the anatomic and echocardiographic knowledge that the normal leaflet coaptation is well below the plane of the mitral annulus; (ii) the natural tendency of the surgeon to tie knots tight; and (iii) the slippery nature of PTFE, which 'runs' much more than other suture material.

The easiest technique to achieve the correct length of the neo-chord is to ignore completely the position of the leaflet's free edge; instead, concentrate on tying it at the level of the annuloplasty ring. Therefore, visualize this plane and tie the first three knots at that level. The assistant then holds these knots with forceps while

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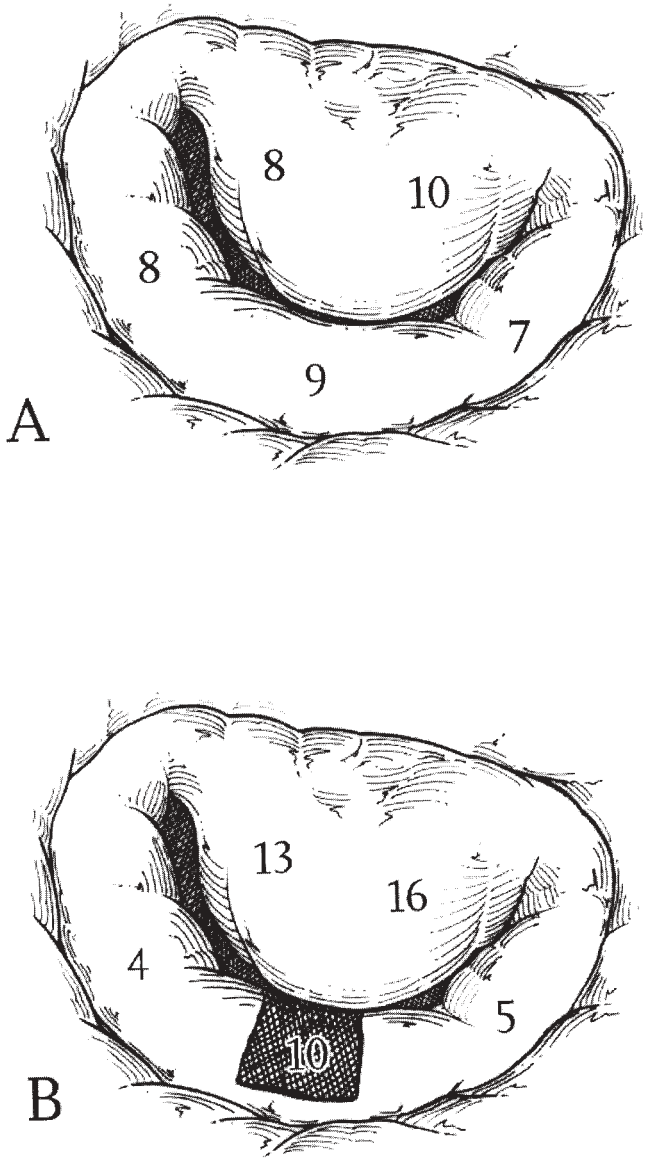

Figure 4: Composite diagram of the mitral valve in 10 patients. A) Numbers represent preoperative location and number of prolapsing segments. B) Number and location of neo-chords. A midposterior quadrangular resection was performed in all 10 patients.

the surgeon 'properly' ties (i.e., tight) the following six to seven knots. This technique can be applied to both anterior and posterior leaflet neo-chords. Valve closure is then tested with fluid. If a leaflet segment is still prolapsing, another neo-chord is placed by passing it through the neo-papillary loop and leaflet edge and tying it with the same technique. If, for whatever reason, the neo-papillary loop is not used, it can be cut out, leaving its anchoring suture in place (which is secured by the two pledgets).

Discussion

Chord replacement with PTFE sutures is becoming increasingly popular because of its availability and proven durability. At a follow up of over 15 years, no case of suture rupture has been reported thus far (5,6). Experimental and clinical studies have shown that after a few months, the chord becomes completely encased within a fibrous sheath, is impossible to differentiate from the other chords, and maintains its strength and flexibility. Although other less expensive sutures, such as polypropylene, are being used in some centers with apparently similar results, the lack of supporting published evidence makes PTFE the material of choice for mitral chord replacement. However, the lack of a standard technique to determine its appropriate length has hampered its wider application.

The senior author (CD) have successfully used the above-described techniques for over a decade. However, to show that these techniques are reliably reproducible, the last 10 cases performed by junior surgeons were analyzed. The mean age of the patients was 51.4 years, and all 10 patients had severe regurgitation due to myxomatous disease with redundant tissue and bileaflet prolapse (Fig. 4A). Five patients underwent simultaneous tricuspid annuloplasty. All patients underwent PML standard quadrangular resection. A long sliding plasty was performed in four patients. Anterior leaflet surface reduction with triangular (n = 1) or horizontal basal (n = 4) resection was performed in five patients (2). One or two neo-chords were implanted in each leaflet segment for a total of 38 neo-chords (Fig. 4B). One or two neo-papillary loops were used in all patients, followed by placement of a Duran flexible annuloplasty ring (mean size 31.8) (Medtronic, Inc., Minneapolis, MN, USA). The intraoperative post-repair transesophageal echocardiogram showed an absence of regurgitation in all patients, with a leaflet coaptation point below the plane of the mitral annulus.

In summary, myxomatous mitral single or bileaflet prolapse can be safely treated with one or more PTFE sutures provided that some simple principles are followed. It is hoped that these techniques will contribute to a larger number of mitral valve repairs.

Acknowledgements

The authors extend their appreciation to colleagues S. Hiro, M. Maxwell, J. H. Oury, and S. Tahta for their unflinching support, and to Jill Roberts for her editorial work. Additionally, they thank Pete Dolan, Senior Medical Illustrator, Medtronic, Inc. (Minneapolis, MN, USA) and Joan Beck, Association of Medical Illustrators Fellow (Minneapolis, MN, USA) for providing the illustrations.

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