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LETTER TO THE EDITOR

Defects and donuts: the importance of the mesh:defect area ratio

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To the Editor:

Techniques in laparoscopic ventral and incisional hernia repair (LVIHR) have changed little since Leblanc and Booth published the first series in 1993 [1] and the bridging repair they described is still widely practised today. In the absence of high-quality studies into operative technique, much of current practice is based on expert opinion and one such example is the widespread acceptance that a mesh overlap of 5 cm in all directions is adequate to minimise recurrence. This is not the result of research, but a misinterpretation of Leblanc himself who stated, in a 2003 review of 200 LVIHR, that a 5-cm overlap was better than 3 cm in terms of preventing recurrence [2]. The fact that a greater overlap correlates with reduced recurrence rate has been borne out by clinical experience, recently reported by Leblanc again in a meta-analysis of over 100 studies [3], but the old dogma recommending a 5-cm overlap remains entrenched [4, 5].

Although we are not aware of any experimental data, a strong mathematical argument can be made to show the need for a greater mesh overlap with larger hernias. This requires that the following facts are agreed:

1. In a bridging repair of a ventral hernia, intra-abdominal pressure creates a constant force pushing against the unsupported mesh.
2. If unopposed, this force would eventually lead to eventration of the mesh through the hernia defect.
3. The forces which oppose eventration—that is, those that keep the mesh in place—come from mesh fixation and tissue ingrowth.

The mathematical argument

Pressure can be defined as force per unit area: $P = F/A$.

This equation can be transformed to $F = PA$, which means that for any given P (intra-abdominal pressure), the force (F) on the unsupported mesh bridging across the defect is proportional to the area (A) of the defect. The larger the defect, the greater the force acting to displace the mesh.

The resistance to the displacing force comes from the fixation and tissue ingrowth, both of which depend on the area of mesh overlap. The greater the area of mesh in contact with the surrounding tissues, the more tacks and/or sutures may be used and the greater the degree of tissue ingrowth.

Consider a round hernia defect of radius r, covered with a circular mesh of radius R. The area of the defect is πr^2 and the area of the mesh is πR^2. The force acting to displace the mesh out through the defect varies with the area of the defect, or πr^2. The force resisting this displacement varies with the area of mesh overlap, which is the donut-shaped area defined by $(\pi R^2 - \pi r^2)$. See Fig. 1.

The relative strengths of the displacing forces and the resisting forces determine whether or not the mesh will migrate through the defect. The ratio of resisting forces to displacing forces is the same as the ratio of the area of the overlapping mesh-donut to the area of the defect, or

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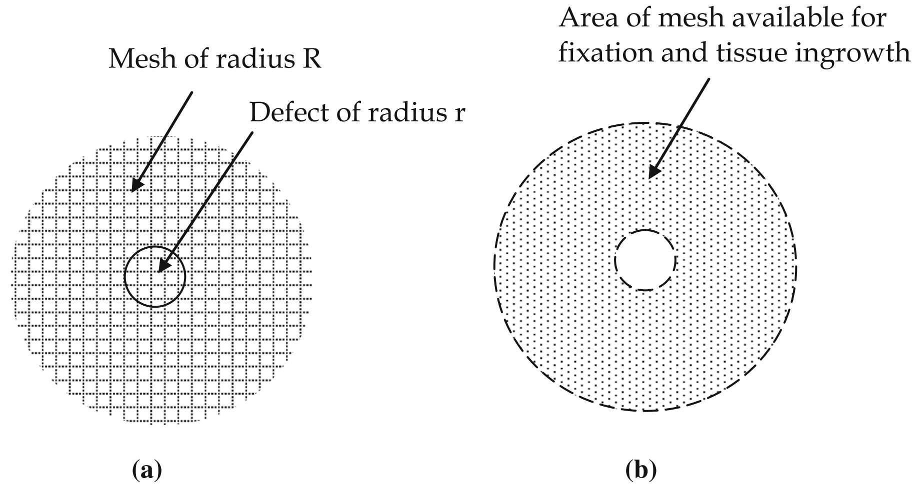

Fig. 1 **a** Diagram of mesh overlapping a ventral hernia defect. The displacing force is proportional to the area of the defect, πr^2. **b** The "donut-shaped" area of mesh that is in contact with surrounding tissues. Its area can be expressed as $(\pi R^2 - \pi r^2)$

$$\begin{aligned}\text{Resisting forces/displacing forces} &= \text{“donut” area/defect area}\\ &= (\pi R^2 - \pi r^2)/\pi r^2\\ &= (\pi R^2/\pi r^2) - 1\end{aligned}$$

The "−1" is easy to explain and easy to ignore. If the mesh has (say) 5 times the radius of the defect, then the mesh area is 25 times that of the defect. However, the area of mesh available for fixation/ingrowth is only 24 times the defect area because of the "hole in the donut".

The mesh:defect area ratio

The equation shows that the ratio of forces varies with the ratio of mesh area and defect area—that is, *the mesh:defect area ratio*. As r (defect size) rises, R (mesh size) must rise proportionally. Thus the length of linear overlap must also increase, in order to preserve the mesh:defect area ratio and maintain the balance between mesh fixation and mesh displacement.

Consider a 2 × 2 cm ventral hernia defect. Many surgeons would accept intuitively that placing a 12 × 12 cm mesh over this is likely to remain secure. The overlap is 5 cm all around and the mesh:defect area ratio in this case is 36. Next consider placing a 20 × 20 cm mesh over a 10 × 10 cm defect. In this case the mesh:defect area ratio is 4. Even though the mesh overlap is still 5 cm, experienced surgeons would appreciate that this is much more likely to fail. The increased likelihood of mesh displacement can be confirmed mathematically as follows: the defect in the second example has 5 times the radius of that in the first, so the mesh-displacing force is 25 times greater. However, the larger mesh in is only 1.66 times the radius of the smaller one so the forces resisting displacement have only risen by $(1.66)^2$, or 2.75. Accordingly, the larger mesh is 25/2.75 = 9 times more likely to migrate through the defect.

What is the "safe minimum" mesh:defect area ratio? This has not been established, but we can estimate it with common sense. From the earlier example one could infer that a mesh:defect area ratio of 36 is adequate but one of 4 is not. Can we narrow it down? A 15 × 15 cm mesh covering a 5 × 5 cm defect gives a ratio of 9. Many of us who have repaired 5 cm umbilical hernias with a 15 × 15 cm mesh have seen mesh migration as a result and would now agree that a larger mesh is better. A 20 × 20 cm mesh over the same defect gives a ratio of 16 and is less likely to displace; indeed, the forces resisting mesh displacement are 16/9 = 1.8 times stronger.

If, for the purposes of this thought experiment, we accept that a ratio of 16 is around the lower limit of acceptability, there are further implications for a laparoscopic repair. Any mesh with a diameter four times that of the defect will have a mesh:defect area ratio of 16, so a 6 × 6 cm defect would require a 24 × 24 cm mesh to achieve this and a 7 × 7 cm defect would require a mesh approaching 30 × 30 cm in size. Such meshes are unwieldy to insert, position and fix. Given that there is barely room in the abdomen for a 25 × 25 cm mesh, especially laterally where space is required for port entry and camera work and where suture and tack placement can be hazardous, aiming for a mesh:defect area ratio of 16 indicates that a 6 × 6 cm defect is about the largest that can be reasonably attempted laparoscopically.

Discussion

The argument proposed here is theoretical. The idea arose from established observations that the risk of mesh migration and recurrence is more common with larger defects and that greater mesh overlap reduces this risk. Thus our theory fits observed facts, although it has not been tested on its own. We are putting it forward here for others to appraise and evaluate.

We have shown that maintaining a 5-cm overlap regardless of the defect size is illogical. Doing so means that the mesh:defect area ratio becomes smaller for larger defects, and mesh displacement becomes more likely. However, this argument is simplistic and overlooks several important factors that impact on clinical practice.

First, it assumes a bridging repair. Defect closure dramatically alters the array of forces acting on the mesh and should, at least in theory, reduce the risk of mesh displacement. There is some evidence for this in the literature [6]. One could argue that defect closure should be a routine practice, but some defects are frankly impossible to close without undue tension. Partial defect closure may be an option in such cases; after all, this would favourably alter the mesh:defect area ratio. Conversely, one could also argue that small defects do not need any closure at all if the mesh is large enough: for example, a 15 × 15 cm mesh over a 1 × 1 cm defect provides a mesh:defect area ratio of 225. The risk of mesh eventration is vanishingly small. Would there be any extra benefit here in closing the tiny defect?

Second, our argument is based on a circular defect in the midline. Although the underlying principles would still apply, the forces described in this article would not apply directly to elliptical or multiple defects, where the radius to use in the calculations would be difficult to define. Peripheral defects are probably different again because forces are undoubtedly different in the flanks and close to bony landmarks. Non-circular meshes also have a different "donut" shape to consider.

Third, it assumes that the overlapping mesh is smooth and flat and fixed to a strong fascial layer. Extraperitoneal fat, and in particular the central strip that is part of the falciform ligament and median umbilical fold, provides a poor bed for mesh fixation and will reduce the strength of the mesh–tissue interface. Wrinkles and folds in the mesh will have a similar effect.

Finally, we recognise that mesh migration is a function not only of abdominal pressure but time as well. In a bridging repair, intra-abdominal pressure provides a constant force pushing outward on the unsupported mesh. Fixation from sutures, tacks and tissue ingrowth resist this force, but such fixation to living tissue is a dynamic process and subject to the "seton effect" over time. Because of the constant intra-abdominal pressure, tacks and sutures will eventually cut through and allow the mesh to migrate. With a strong force such as a sudden cough, this could occur very quickly, but with "normal" intra-abdominal pressure it typically takes a year or more and is recognised as pseudorecurrence [7].

Conclusion

There are still many surgeons who bridge defects without closure believing that a 5-cm mesh overlap is adequate. This figure was not derived from scientific study and there is mounting clinical evidence to suggest that larger defects require more overlap. We have now provided mathematical confirmation of this concept. We recommend that surgeons reflect on their practice: close defects where appropriate, consider the mesh:defect area ratio instead of the arbitrary 5-cm "rule", and even abandon laparoscopy altogether in favour of open repair when the numbers simply do not add up.

Compliance with ethical standards

Conflict of interest The Authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by the authors.

Informed consent None.

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