

Boundary Indication Pugh Matrix Research:

Objective: Evaluate 5 different boundary indication modalities

	Laser Feedback	Audio Feedback	Image Overlay	Visual Proximity Meter	Ink	Standard: Do Nothing
Able to integrate with the cutting tool	1	1	1	1	0	0
Feasible to solve	-1	1	-1	1	1	0
Able to stay localized on the boundary	0	1	1	1	0	0
Unintrusive to use	1	-1	1	1	1	0
Total	1	2	2	4	2	0

The second barrier that needs to be overcome by our solution is making sure that the surgeon is able to keep track of the boundary. It's completely unhelpful to find the boundary if they're unable to keep track of it in order to make the cut at the right location. So there is need for a way to keep track of the boundary in order to guide the tool to the proper location. We examined 5 different feedback modalities: Laser Feedback, Audio Feedback, Image Overlay, Visual Proximity Meter, and Ink. Our results are summarized in the Pugh Matrix above and expanded upon in the research below.

Laser Feedback:

The basic idea behind this solution is to place a laser line on the surface of the tissue. This laser would be targeted at the specific location of the boundary that would be detected using one of the technologies discussed in the detection Pugh matrix. This would have the benefit of having high resolution.

The problems with this technology are multifold. The first is that there would need to be a separate laser tool that would need to be inserted into the body. Then there would need to be an advanced tracking algorithm to determine exactly where the laser is coming from and the exact angle that it needs to be at to place the laser at the boundary.

There is potential to get a little more creative with the laser placement by integrating it either with the cutting tool or by placing some kind of marker on the surface of the tissue that generates the laser at the proper location based upon the detection mechanism.

Audio Feedback:

The basic idea behind this solution would be to integrate an audible tone that changed based upon the distance away from the boundary. This tool would require integration with some form of tracking. A sensor would be placed onto the cutting tool and this would be tracked by the detection tool which holds the place of the boundary relative to reference points. Ultimately one drawback of this technology would be that it might be somewhat annoying over the course of a very long surgery no matter how much work was placed into making the tone not too grating.

Image Overlay:

The basic idea behind this solution would be to use image processing to track the precise location of the boundary on the visual field of the laparoscopic camera and to display a line that the surgeon could cut along to cut precisely on the boundary. The one immediate barrier to this solution is the vast amount of image processing that would need to be performed to ensure that the boundary is as precise as possible. The complexity would only increase as the camera moves or the tissue is shifted during the course of the surgery.

Visual Proximity Meter:

The basic idea behind this solution would be to integrate a visual meter that would allow the surgeon to visualize how far the cutting tool is away from the boundary. This method is similar in many ways to the Audio Feedback solution discussed above but instead of an audible tone the feedback is given in the form of a visual dial. This dial would track the lateral movement across the tissue instead of 3 dimensions. This dial could be overlaid onto the surgical view and would seamlessly allow the physician to monitor their distance from the boundary in real time.

Ink:

The basic idea behind this solution would be to mark the boundary with some form of ink during the boundary detection process. This could be integrated into a separate surgical tool or could be integrated as the boundary is identified. One problem with this method is that it would suffer from limited resolution and would also potentially have difficulties in maintaining the precise location of the boundary over time. The ink would need to be resistant to the blood that is everywhere during the surgery. It would also be subject to noise from the different tissue types that are present at the surface of the prostate-sphincter boundary.

