The Use of Force-Sensing Magnetic Anchors to Characterize Compression Stricturoplasty in a Porcine Model of Ileocolonic Stricture

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Background

The use of temporary magnets for magnetic compression stricturoplasty (MCS) has been reported anecdotally[1]. Leveraging our group's success in creating GI tract anastomoses with magnetic compression[2], **we sought to characterize the progression of MCS by using novel force-sensing magnetic anchors in a porcine model of ileocolonic stricture.**

Methods

Design of Compression System with Integrated Ultraminiature Sensor Array

Two magnetic device components, "anchors", were designed to be placed immediately flanking a stricture. The distal anchor included an array of ultraminiature sensors which captured and transmitted data to an external module (Figure 1). The anchors were designed to progressively compress interposed fibrotic stricture to bring about central tissue necrosis and peripheral remodeling.

Magnetic Compression Stricturoplasty Technique

Using a recently reported technique[3], an ileosigmoid fibrotic stricture was developed in 3 pigs. Anchors were placed through a combination of open and endoscopic techniques.

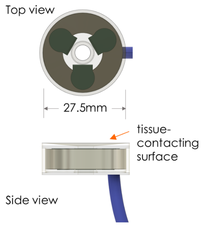


Figure 1. Device design

MCS progression and stricture length were monitored from sensor data and with x-ray analysis. Endoscopy was performed at designated timepoints. After euthanization, necropsy was performed for macroscopic evaluation. *En bloc* tissue was fixed and sliced for histopathologic analysis.

Results

Achievement of Magnetic Compression Stricturoplasty

Anchor placement was successful. All pigs tolerated the procedure, maintained weight, and did not demonstrate signs of infection, leak, or perforation. Compression stricturoplasty occurred within 6 days. The post-intervention cross-sectional area of the lumens (Figure 2b) were **2.5-4x larger than the pre-intervention lumens** (Figure 2a). Gross evaluation revealed successful stricture excision, and healthy-appearing surrounding mucosa; histology confirmed these findings, with re-epithelialization and intact mucosa.

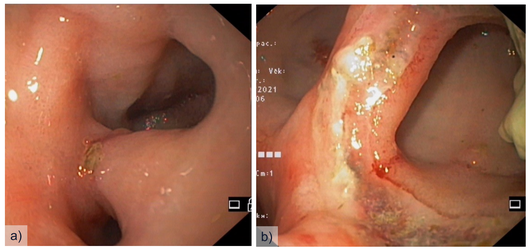


Figure 2. a) pre-intervention strictured lumen (top) b) newly patent lumen

Multi-Phase Stricture Response to Compression Therapy

3 distinct stages of the stricture response to MCS were discernable (Figures 3 and 4). We hypothesize that stage 1 is dominated by compression of nonfibrotic tissue, stage 2 by compression of fibrotic tissue, and stage 3 by central necrosis and peripheral remodeling.

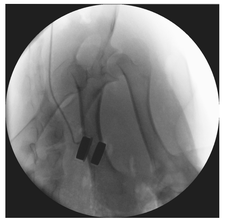


Figure 3. X-ray showing compression of stricture by anchors

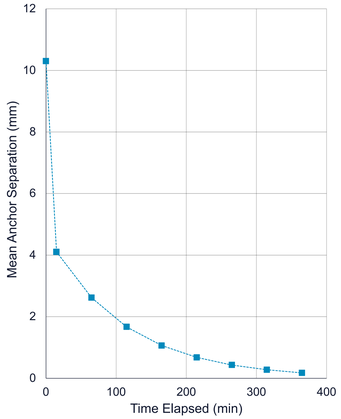


Figure 4. Stages of stricture response. Stage 1 is characterized by a rapid decrease in stricture length to half of its initial value. In Stage 2, stricture length decreases to less than 10% of its initial value, with stricture length modeled by a decaying exponential function. In Stage 2 thickness is largely stable.

Discussion

- We demonstrated MCS in an ileocolonic stricture, with excision of strictured tissue and formation of a healthy widened lumen in 6 days.
- We observed 3 stages of MCS.
- Our approach is adaptable to endoscopic delivery, and could be an effective, minimally invasive alternative to surgical stricturoplasty.
- Anchors apply longitudinal compressive forces, avoiding the potentially traumatic radial outward force applied by current endoscopic therapies.
- The ability to provide real-time feedback of MCS progression would allow for precise outpatient monitoring in a clinical setting.



Figure 5. A necrotic scar tissue disk 19 mm in diameter excised by the anchors

Conclusion

Further studies are needed to characterize and understand the efficacy of MCS as an alternative to endoscopic therapy and/or surgical stricturoplasty.

References
1. Woo et al., *Surg Innov*. 2017
2. Muensterer et al., *Pediatrics*. 2021
3. Lukas et al., *Surg Endosc*. 2021

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