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ORIGINAL STUDY

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Biochemical and biomechanical influence on peri anchor cyst formation in rotator cuff repair

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This review aims to provide a detailed analysis of the pathological processes underlying peri anchor cyst formation. As a consequence providing methods that can be implemented to reduce cyst occurrence and also to highlight areas of current weakness in the literature that could be strengthened so as to improve our ability to manage peri anchor cyst formation.

We performed a literature review of the National Library of Medicine focused around rotator cuff repair and peri anchor cysts. We summarise the literature whilst incorporating a detailed analysis of the pathological processes underpinning peri anchor cyst formation.

There are two theories behind peri anchor cyst occurrence, biochemical and biomechanical. It is our belief that cyst formation occurs as a result of both. The biochemical make up of an anchor plays a crucial role in cyst occurrence and it's timing post-operatively. Consequently anchor material plays a vital role in peri anchor cyst formation. Tear size, degree of retraction, number of anchors and varying bone density within the humeral head are all important biomechanical factors.

Further investigation is required into certain aspects of rotator cuff surgery to improve our understanding of peri anchor cyst occurrence. From a biomechanical perspective these include: Anchor configuration to both the tear and each other and also tear type itself. From a biochemical perspective we need to further investigate the anchor suture material. It would also be of benefit if a validated grading criteria of peri anchor cysts was produced.

Keywords: Peri anchor cyst; rotator cuff; rotator cuff tear; arthroscopy; shoulder.

INTRODUCTION

Peri anchor cyst formation is a recognised sequelae of arthroscopic rotator cuff repair surgery and has been well described in previous literature *(1,2)*. However whilst its occurrence and potential impact on cuff repair and revision surgery has been

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well documented, the pathophysiology behind its occurrence is still a topic of much debate. Consequently this has led to a void in the literature regarding the most appropriate methods to avoid cyst occurrence, therefore reducing our ability to negate the potential complications such cyst formation poses.

This is further compounded by a lack of consistency regarding peri anchor cyst definition and therefore its consequent validated classification and reported occurrence rate *(3)*. As a result, forming a valid consensus from the individual pieces of work being produced can prove to be rather difficult.

The primary aim of this literature review was to assess the currently available literature regarding peri anchor cyst formation in rotator cuff surgery in order to evaluate the different theories regarding cyst formation and review the methods that could be implemented to reduce cyst occurrence.. Secondarily we wanted to offer potential areas that should be evaluated in the future to guide further studies relating to this topic which is relatively under reported in currently published literature. Hopefully as a consequence our understanding of peri anchor cyst formation can develop and its impact on arthroscopic rotator cuff repair and revision surgery can be reduced.

MATERIALS & METHODS

We reviewed literature from the National Library of Medicine focused around rotator cuff repair and peri anchor cysts. We then related this research to the pathophysiology behind peri anchor cyst occurrence.

DISCUSSION

Multiple theories regarding the pathophysiology behind per anchor cyst occurrence have been explored. These are largely encompassed by two over-arching potential mechanisms which include biomechanical stress of the anchor and local tissue biochemical reaction to the anchor *(4,5)*. It is our opinion that cyst formation likely occurs through a combination of both.

To fully appreciate the biochemical theory behind peri anchor cyst formation an appreciation of the underlying science must be achieved. This naturally would primarily apply to bioabsorbable anchors more than nonabsorbable anchors. This is excellently explained in detail by Williams and Johnson when investigating bioabsorbale screws in knee surgery *(6)*. We have tried to summarise this and specifically relate to peri anchor cyst formation in arthroscopic rotator cuff surgery.

At a molecular level bioabsorbable anchors are polymers of Polylactic Acid (PLA) and Polyglycolic Acid (PGA). The variety of bioabsorbable anchor materials relates to the molecular compositions of the PLA and PGA polymers and this is crucial in determining their biomaterial characteristics. An umbrella term of lactic acid and glycolic polymers (PLAGA) may be used to encompass these. Specifically of concern regarding this in our review is the impact these PLA/PGA polymer variants have on anchor resorption and local inflammatory response as these factors impact peri anchor cyst formation.

The biochemical mechanism of peri anchor cyst formation can be divided into two broad processes. One relates to the degradation of the anchor itself and the other to the inflammatory process of the local tissue environment. Once in vivo PLAGA anchors absorb water which initiates the degradation process. Initially this is known as homogenous degradation whilst the mass of the anchor is constant and consequently the rate of anchor degradation is stable. Once the mass of the anchor decreases the rate of degradation begins to increases exponentially in a process known as autocatalysis. The anchor undergoes ester hydrolysis by acids in the local tissue, as the PLAGA polymers are terminated by acid groups. This acid group catalyses the cleavage chain ester group which then generates a carboxyl end group which increases local acidity. Consequently the exponential increase in acidity surrounding the anchor causes the exponential increase in anchor degradation. Crucially, it is this acidic nature of the local tissue that is responsible for biochemical cyst formation. This process in summarised in Figure 1.

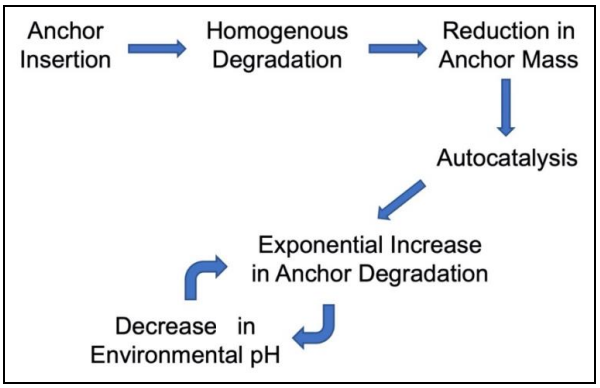

Figure 1. — Flow chart summarising the biochemical degradation process of PLAGA anchors.

Kulkarni et al noted PLA rich polymers were more resistant to aqueous media degradation than PGA-rich polymers hence various combinations of these polymers being produced by manufacturers to try to optimise anchor characteristics such as rate of absorption *(7)*. This is particularly well demonstrated in a recent prospective study by who compared 3 different biocomposite anchors and demonstrated varying cyst occurrence rate, the lowest in a 30% beta tricalcium phosphate (TCP) /70% PLAGA anchor *(8)*.

Also of importance is the anchors response to the above process. The PLAGA anchor produces oligomers that escape its structure to eliminate the ester bonds causing autocatalysis. However oligomers in the internal matrix of the anchor are unable to escape unlike the oligomers on the anchor surface. Consequently ester bond elimination occurs at a lower rate in the centre of the anchor than the surface. The importance of this in relation to cyst occurrence is that smaller anchors have a smaller internal matrix and therefore a relatively higher surface area that can release oligomers to eliminate ester bonds. This leads to a reduction in the rate of the degenerative process of smaller anchor and a reduction in the severity of the local inflammatory response in comparison to larger anchors. In turn this leads to a less acidic local environment and therefore a lower risk environment for peri anchor cyst occurrence. The theoretical conclusion being a smaller anchor will create a smaller cyst.

Cleary when attempting to manufacture the 'optimal' bioabsorbable anchor there are more characteristics that need to be taken into consideration than the risk of peri anchor cyst formation alone though. For example whilst a larger anchor may produce a more acidic environment, it offers the theoretical advantage of increased stability and consequently less micromotion- a biomechanical risk factor for cyst formation that will be discussed in more detail *(9)*.

Secondly, the local inflammatory process induced by bioabsorbable anchors is a biochemical cause of cyst occurrence. The primary inflammatory response begins at time of anchor insertion. The initial severity and duration of this response is determined by the rate of anchor absorption which as previously stated is largely determined by its PGA and PLA composition. The secondary response occurs through release of soluble material from the anchor as the degeneration process occurs. This is either dampened or exacerbated by the anchor's innate ability to crystallise post degradation or produce crystalline residue. This ability decreases the inflammatory response however varies depending on polymer composition. Therefore the anchor polymer composition is crucial in determining likelihood of occurrence and timing of peri anchor cyst formation. This indirectly relates to risk and time of occurrence of peri anchor cysts. This is supported by Chung et al. who noted a decrease in cyst presence at MR scanning 18 months post op compared to 6 months and also a decrease in cyst size *(10)*. Whilst it must be noted that this prospective study was of a relatively small cohort of 40 patients and only assessed 1 anchor, it would support the biochemical theory. Peri anchor acidity secondary to degradation of the anchor or the local inflammatory response is likely to be reduced at 18 months post-operatively and therefore less important in causing cyst formation.

Whilst there is clear biochemical explanation for why bioabsorbable anchors may cause peri anchor cyst formation, cyst formation in non-absorbable anchors is also a well-established phenomenon. In fact it has been demonstrated that certain bio-absorbable anchors demonstrate a lower rate of peri anchor cyst occurrence in comparison to

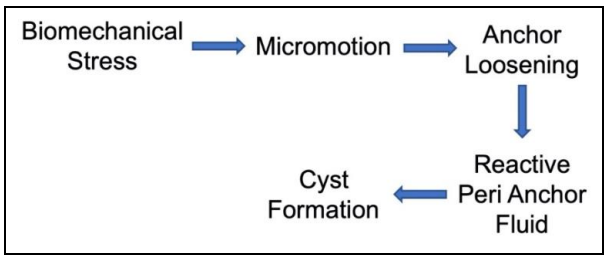

Figure 2. — Flow chart demonstrating the process of peri anchor cyst formation through biomechanical stress.

non-absorbable Poly Ethyl Ethyl Ketone (PEEK)) anchors *(11)*. Consequently this leads us to believe a combination of factors must be in play regarding peri anchor cyst formation.

Biomechanical stress to the anchor is thought to lead to micromotion of the anchor itself in the humeral head *(12)*. Such micromotion in turn causes a combination of loosening and reactive peri anchor fluid formation thereby causing cyst formation to occur. This theory is supported by work demonstrating a link between larger cuff tears and an increased rate of cyst formation. The resulting hypothesis being that larger tears lead to an increased force being transmitted through the repair and therefore through the anchors themselves. This leads to increased stress to the anchors, the sequelae being an increase in micromotion, increasing the risk of cyst formation *(3)*. This process is demonstrated in a flow chart in figure 2.

Chung et al prospectively assessed a cohort of 40 patients post arthroscopic cuff repair with biocomposite anchors for peri anchor cyst formation. They noted a statistically significant link between larger tears and cyst formation on AP dimension MR scanning at 6 and 18 months post operatively. Of note, they also noted a link between increased tear retraction and larger cyst formation. They theorized the increased length of retraction leads to increased forces applied across the repair and consequently increased stress and micromotion to the anchor *(10)*. Again this would add substance to the theory that biomechanical anchor stress contributes to the risk of cyst formation.

This theory is further supported by Ro et al. They retrospectively assessed the rate of peri anchor cyst formation in 215 patients, comparing all suture, bioabsorbable and polyether ether ketone (PEEK) anchors *(13)*. On regression analysis they found a link between re tear rate and larger cysts. This differs from previous literature showing no link between re tear rate and cyst size *(6,10,14)*. A link between larger tears and larger cyst formation was also noted, supporting the biomechanical stress theory of peri anchor cyst formation *(3)*.

Additionally Chung et al found a clinically significant propensity for cyst occurrence in the greater tuberosity located anchors than the lesser tuberosity located anchors. They proposed that this may be due to increased bone density of the relatively cortical bone of the lesser tuberosity when compared to the less dense more cancellous in nature bone of the greater tuberosity *(10)*. Increased bone density provides a stronger fixation of bone anchors and therefore decreased micromotion of the anchor. This finding was also supported by Fritz et al. who noted an increased rate of cyst formation in the greater tuberosity following supraspinatus or infraspinatus tendon repair *(15)*. It has also been suggested differences in bone density could be the reason behind increased failure rate in medial row anchors compared to lateral row anchors *(16)*. However this is disputed by other literature. Barber et al assessed humeral head bone density and consequent anchor pull out strength in a cadaveric study and found no notable difference in bone density or consequent pull out strength between the greater and lesser tuberosities *(17)*.

Vonhoegen et al. have offered an alternative to the biomechanical stress theory *(18)*. Their retrospective review of single row vs double row repairs with a biocomposite anchor demonstrated a lower rate of peri anchor cyst formation with the single row repair compared the double. Notably there were no severe cysts in the single row cohort. Given that the use of more anchors biomechanically results in a greater sharing of load therefore putting less stress on individual anchors, it would be expected the double row cohort would have a lower rate of cyst formation. Consequently a theory has been postulated that more anchors increase intraosseous pressure in the humeral head causing a consequent reduction in tubercular majus blood flow which

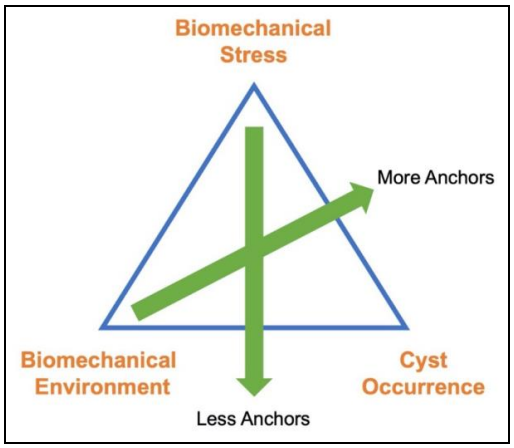

Figure 3. — Diagram demonstrating the relationship between number of anchors and the impact this has on the biochemical environment of the humeral head vs the biomechanical effect it has on rotator cuff repair strength.

in turn increases the likelihood of cyst formation *(18)*. However it is our belief that the increased number of bioabsorbable anchors in the humeral head leads to an increase in anchor degradation and local inflammatory response. This causes a relative drop in pH of the local tissue and a higher risk environment for per anchor cyst formation. We have demonstrated the relationship that number of anchors has with biochemical and biomechanical factors linked to cyst occurrence in figure 3.

Whilst various aspects of peri anchor cysts have been investigated in the literature, it is of our opinion there are multiple areas that can still be explored based upon the theories of peri anchor cyst formation. Primarily these are based on confounding factors related to the biomechanical and biochemical theories of cyst occurrence. It is clear that a balance between the biomchemical and biomechanical theories exists when considering the optimal rotator cuff anchor in regards to peri anchor cyst formation. In summary this is the negative biochemical effect of multiple anchors vs the positive effect of multiple anchors from a biomechanical perspective.

Regarding the biochemical theory. To our knowledge current literature only explores the material of the anchor itself. However there are 2 functional units to an anchor construct in rotator cuff repair; the anchor and the suture or tape. The role the suture plays in the degradation process of the anchor and on the inflammatory response of the local environment has not been assessed. In many anchor constructs the suture overlays the anchor and is therefore the point of contact of the bone-anchor interface rather than the anchor. Therefore suture characteristics including material, braiding, stiffness, coarseness may all play a role in peri anchor cyst occurrence. However their impact is currently unknown.

Regarding biomechanical stress, number of anchors, cuff tear size and anchor material have been discussed. However as far as the authors are aware nothing in the literature has explored anchor configuration, be that to each other, to the tear itself or in relation to the biomechanical loading of the tear and consequently the repair itself. Also to our knowledge no work has been completed comparing tear type and likelihood of cyst occurrence. Tear type would impact on anchor position in relation to cuff tear and consequently biomechanical stress to the anchor itself. These factors are crucial in load distribution and therefore play an important role in the amount of biomechanical stress applied to an anchor.

This study provides a detailed review of the underlying science behind the primary factors relating to peri anchor cyst occurrence along with reviewing currently available literature analysing these factors. As a consequence it provides a useful summary of the current problems surrounding peri anchor cyst occurrence whilst explaining the pathological processes behind this. It also highlights potential areas that can be addressed in the future to improve our management of this difficult sequelae of rotator cuff repair.

CONCLUSION

Biomechanical stress and biochemical properties of anchors used in arthroscopic rotator cuff repair play crucial roles in peri anchor cyst occurrence. Unfortunately the relationship between these factors and how they interlink is poorly understood. Whilst the presence of peri anchor cysts does not seem to have a detrimental impact on quality of cuff repair and patient outcome, it plays a significant

role in revision rotator cuff surgery. Whilst surgical technique may combat the presence of peri anchor cysts in revision surgery, ultimately reducing cyst occurrence following the primary surgery is preferred. By focusing our efforts on increasing our understanding of the mechanisms behind cyst occurrence, primarily investigating the importance of anchor configuration and tear type from a biomechanical perspective and the role anchor suture plays from a biochemical perspective we can achieve this goal. Also the importance of producing a validated system for the grading of peri anchor cysts cannot be underestimated as this will ensure a higher degree of consistency within the literature base. Finally, an algorithmic process to aid our understanding of the symbiosis between the multiple factors discussed in the above review would be of benefit as more reliable conclusions on how best to combat cyst occurrence could be produced.

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