Iatrogenic articular cartilage injury: the elephant in the orthopaedic operating room

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Arthroscopy of the synovial joint is the most frequently performed orthopaedic procedure in the developed world.[[1]] A variety of soft-tissue and articular pathologies relating to the hip,[[2]] knee, ankle, shoulder, elbow and wrist joints can be treated arthroscopically.[[1]] While advances in instrument design and optical technology have dramatically improved arthroscopic surgery, the basic technique of joint arthroscopy has remained unchanged since its introduction over a century ago.[[1]] The joint is distended with an irrigating solution, and the joint pathology addressed through passage of arthroscopic surgical instruments, using peri-articular portals. Although synovial joints are well-adapted to withstand and adapt to years of physiological loads, its key component, the articular cartilage, is surprisingly susceptible to iatrogenic injury,[[3]] a phenomenon we label iatrogenic Articular Cartilage Injury (iACI).

Saline (0.9%) or Hartmann's solution, are the most commonly used joint irrigating solutions in modern joint arthroscopy. These solutions alter the extracellular osmolarity within the joint because synovial fluid, which is in due course drained from the joint, has an osmolarity considerably higher (~400 mOsm) than the irrigating solutions (~300 mOsm) that replace it.[[4]] The net result is a decrease in extracellular osmolarity within the synovial cavity with

consequent swelling of not only the articular chondrocytes, but also the soft tissues within the joint cavity due to this non-physiological osmotic gradient.[[5]] Indeed, 0.9% saline and Hartmann's solutions were manufactured for intravenous administration and designed to be iso-osmolar with plasma (~300mOsm). Their use in joint arthroscopy was simply circumstantial and convenient, and not supported by any definitive joint physiological studies.

It is important to note, however, that the temporarily decreased osmolarity within the synovial cavity during arthroscopy does not appear to be harmful *per se*, as it simply reverses once the solutions are drained from the joint and replaced again by synovial fluid. The iACI occurs because during this transient period of decreased osmolarity, the articular chondrocytes become much more susceptible to mechanical trauma, and this period also coincides with the actual arthroscopic surgical procedure.[[4,6]] Such mechanical trauma occurs frequently during the surgical procedure, from scalpel blades, trochars, motorised shavers, arthroscopic instruments, cutters, drills, screws, implants or circular osteotomes, which are used to treat a variety of soft-tissue and articular pathologies.[[3,6,7,8]] While the precise physiological rationale for this chondrocyte susceptibility to mechanical injury in hypo-osmolar environments still remains to be established, experimental studies in human and animal cartilage strongly suggest that this is due to chondrocyte swelling from the decreased extracellular osmolarity.[[5,7]] This theory is supported by an *in vitro* study where chondrocyte death during drilling for screw fixation (due to thermal and mechanical trauma), is markedly reduced with copious irrigation with a hyperosmotic saline solution.[[6]] The theory is also supported by *in vivo* (rat) experiments, which have demonstrated that hyperosmolar saline is chondroprotective against scalpel injury, presumably due to chondrocyte shrinkage.[[7,8]]

The evidence from translational studies is clear. iACI results in focal damage to the joint articular cartilage. Such focal articular cartilage injury has been considered to be 'unquestionably the most common iatrogenic lesion in arthroscopic surgery'.[[9]] The incidence of these lesions has rarely been formally reported or studied, probably because it **is** the elephant in the operating theatre. But does it matter? After all, there is no mass epidemic of degenerative joint disease after arthroscopy. However, like neurons, cartilage cells in the adult have, in common, the inability to divide. Thus, the neurons and cartilage cells with which we enter adult life have to last through our remaining years. Moreover, in contrast with other joint tissues (bone, synovium), because of the avascular nature of articular cartilage, there is very limited capacity for producing 'repair' tissue, which is, in any case, mechanically weak fibro-cartilage.

Cartilage is also prone to avoidable damage during open procedures on the joint surfaces, such as internal fixation of intra-articular fractures, trochleoplasty and partial knee arthroplasty, when drying can kill the chondrocytes.[[8,10,11]] This can happen within 30 minutes, and is accelerated in laminar flow environments.[[12]]

Although some patients may have a genetic predisposition [[13]] that weakens the cartilage, making them more prone to osteoarthritis, and some have a genetic mutation that causes structural changes [[14]] that result in abnormal loading of the cartilage, in the majority of patients there is no underlying predisposition to injury. Therefore, we believe, everything possible should be done to protect native articular cartilage, as chondrocytes are not replaced after skeletal maturity. Various chondroprotective strategies have been proposed which are aimed at decreasing cartilage loss such as weight loss and shock-absorbing insoles.[[15]] Meniscal transplantation[[16,17]] and procedures to realign limbs that help to optimise the direction of the applied load,[[18]] may also have a role in maximising shock absorption. In normally-aligned uninjured limbs, biological agents such as Salubrinal[[19]]

and Torin 1,[[20]] and even mRNA manipulation, may have a role in maintaining cartilage health, but these are still at an early stage of development. It is clearly essential for surgeons to prevent all avoidable iatrogenic injuries, which have been reported with a range of procedures,[[21,22]] however, iACI is particularly insidious as it may not be immediately evident to the surgeon.

A simple strategy to protect the articular cartilage during arthroscopy (chondroprotection), would be to increase the osmolarity of the joint irrigation solution so that it is similar to, or indeed higher than that of synovial fluid, for that 'extra' protection from the inevitable mechanical and thermal trauma that occurs during articular surgery.[[3,6-8]] Safety of hyperosmolar irrigation solutions has recently been established in shoulder arthroscopy.[[23]] This Level 1 RCT interestingly also noted significantly decreased post-operative pain (from less soft-tissue extravasation) in the hyperosmolar group.[[13]] There is a need to perform large, prospective, double-blinded multicentre randomised controlled trials to determine the cost-effectiveness of hyperosmolar joint irrigation solutions. Findings from such trials may help improve the clinical outcome for the most commonly performed orthopaedic surgical procedure, that of joint arthroscopy. Such Level 1 studies may be readily conducted and delivered because a) large numbers of these procedures are performed worldwide each year ensuring good recruitment; b) double-blinding would be straightforward, unlike many other trials of surgical techniques and c) no change in surgical technique is required, only the irrigating solution is modified.

It is perhaps time to deal with the elephant in the operating theatre.

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