TREATMENT OF JOINT INJURIES: PAST, PRESENT AND FUTURE
Table of Contents

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# Table of Contents

**Introduction** ........................................................................................ 1

**Meniscus Tears of the Knee** ........................................................................ 2

**Total Hip Replacement** ............................................................................... 12

**Rotator Cuff Tears** ................................................................................ 30

**The Role of Tissue Engineering in Radiology** .................................................. 37

**The Impact of Technology on Radiologic Technologist** ........................................ 44

**Curriculum Vitae** .................................................................................. 56

---

**List of Figures**

Figure 1. Posterior view of right knee .............................................................. 3

Figure 2. Lateral view of right knee ................................................................. 3

Figure 3. Meniscus views of right knee ............................................................ 4

Figure 4. Examples of meniscal tear ............................................................... 5

Figure 5. AP right knee positioning and AP left knee radiograph ................. 6

Figure 6. Lateral right knee positioning and lateral right knee radiograph ... 6

Figure 7. Injection of contrast for right knee arthrogram ............................ 6

Figure 8. Positioning of the medial and lateral meniscus ............................. 8

Figure 9. Normal knee arthrogram medial meniscus ..................................... 9

Figure 10. Double contrast meniscal tears ..................................................... 9

Figure 11. Normal MRI of knee ................................................................. 10

Figure 12. Inferior meniscus margin tear ...................................................... 12

Figure 13. Normal meniscus margin tear ...................................................... 12

Figure 14. AP sublux and radiograph ......................................................... 13

Figure 15. Fracture of femoral head ............................................................. 16

Figure 16. Fracture of femoral head ............................................................. 16

Figure 17. Fracture of femoral head ............................................................. 17

Figure 18. Fracture of femoral head ............................................................. 17

Figure 19. Fracture of femoral head ............................................................. 17

Figure 20. Fracture of femoral head ............................................................. 17

Figure 21. Fracture of femoral head ............................................................. 17

Figure 22. Partial rotator cuff tear ............................................................... 32

Figure 23. AP external rotation shoulder .................................................... 33

Figure 24. AP internal rotation shoulder .................................................... 33

Figure 25. Cystic erosion and partial rotator cuff tear ................................. 34

Figure 26. Double tuberosity shoulder ....................................................... 34

Figure 27. Needle placement and normal shoulder arthrogram .................... 35

Figure 28. Axial, coronal and sagittal planes ............................................. 37

Figure 29. MRI views ................................................................................ 37

Figure 30. Horizontal sutures and vertical sutures ....................................... 40

Figure 31. Meniscal fixation device ............................................................ 40

---

iii
List of Figures

Figure 1. Posterior view of right knee ............................................................. 3
Figure 2. Lateral view of right knee ................................................................ 3
Figure 3. Meniscus views of right knee ........................................................... .4
Figure 4. Examples of meniscal tears ............................................................... 5
Figure 5. AP right knee positioning and AP left knee radiograph ............... 6
Figure 6. Lateral right knee positioning and lateral right knee radiograph .... 6
Figure 7. Injection of contrast for right knee arthrogram ......................... 6
Figure 8. Positioning of the medial and lateral meniscus ......................... 8
Figure 9. Normal knee arthrogram medial meniscus ................................ 9
Figure 10. Double contrast meniscus tears ...................................................... 9
Figure 11. Normal MRI of knee .................................................................. 10
Figure 12. MRI meniscus tears of the medial meniscus ............................... 12
Figure 13. Inferior meniscus margin tear ...................................................... 12
Figure 14. Complex tear of lateral meniscus ............................................... 12
Figure 15. Frog leg position ........................................................................ 13
Figure 16. Cross table lateral hip ................................................................. 13
Figure 17. Fractures of the proximal femur ............................................... 14
Figure 18. Trabeculae of femoral head ......................................................... 15
Figure 19. Pauwels classification of intracapsular fractures ...................... 17
Figure 20. Garden staging of subcapital femoral fractures ......................... 18
Figure 21. Blood supply to proximal femur ............................................... 19
Figure 22. Humeral crescent sign ................................................................. 20
Figure 23. Bilateral femoral head crescent signs ................................. 20
Figure 24. Avascular necrosis ..................................................................... 21
Figure 25. Classic signs of degenerative joint disease .............................. 22
Figure 26. Prosthesis ................................................................................ 23
Figure 27. Step 1 and 2 Biomet implant ...................................................... 28
Figure 28. Step 3 and 4 Biomet implant ...................................................... 29
Figure 29. Final Biome result ..................................................................... 29
Figure 30. Anterior view of right shoulder ................................................. 30
Figure 31. Posterior view of right shoulder ................................................. 31
Figure 32. Normal rotator cuff ................................................................... 31
Figure 33. Partial rotator cuff tear ............................................................... 32
Figure 34. AP external rotation shoulder ..................................................... 33
Figure 35. AP internal rotation shoulder ..................................................... 33
Figure 36. Cystic erosion and partial rotator cuff tear ................................. 34
Figure 37. Double tuberosity shoulder ........................................................ 34
Figure 38. Needle placement and normal shoulder arthrogram ............... 35
Figure 39. Axial, coronal and sagittal planes ........................................... 37
Figure 40. MRI views .......................................................... 37
Figure 41. Horizontal sutures and vertical sutures ..................................... 40
Figure 42. Meniscal fixation device ............................................................ 40
Fractured bones and joint injuries compose the majority of exams and revenue in the diagnostic radiography department. Patients, both young and old, are radiographed for fractured hips, knees and dislocated shoulders that are caused by falls, sport injuries or accidents. How radiographers image joint injuries is set by hospital policy and standard exam procedures. However, treatment has evolved over the last twenty years and changing patient diagnostic protocols have had an impact on the radiography department. Twenty years ago, injuries would involve one exam for diagnosis and then a later exam to evaluate the healing process. Now, joint injuries may require multiple images taken over the course of healing, to include diagnosis and the healing progress or fluoroscopy for guidance in new repair techniques. This thesis will examine the evolution of menisci diagnosis, hip fractures that use total hip implants, and rotator cuff injuries and how the evolution of these joint diagnoses has impacted radiologic resources.

Joint injuries can occur in all ages from the very young to the aged. In the past, most injuries were accident or work related, but there has been a significant increase in joint injuries in sports that include the preteen through the adult sector. Severe injuries are occurring in younger populations and patients demand the most advanced technology to quickly fix and repair the injury. Patients want fast repair of their injury so that they can start rehabilitation and return to normal activity. The young are not the only age group demanding fast and better repair. The aged, especially in hip repairs, need quick recovery. The aged heal more slowly and complications from hip fractures may prolong recovery or cause death. New technologies assist with more accurate diagnosis and treatment, restoring patients to a normal life style in a timely fashion and potentially increasing their longevity. Although we have good surgical techniques for repair and
prosthetic restoration of fractured joints, there is a demand for recovery to be faster and
type better.

**Meniscus Tears of the Knee**

The largest joint in the body and the most vulnerable to injuries is the knee (Greenspan 8.1). The hinged joint of the knee is primarily an articulation of the femur and tibia and is restricted in its movements by flexion and extension. The knee is composed of the femoral condyles articulating with the tibial platform with a sellar joint between the patellar surface and the femur. In complete extension, the tibia has some lateral rotation due to the slight concave condyles of the tibia, while the femur has some medial rotation. The knee joint is encapsulated by a fibrous sheath and synovial membrane. The fibers run from the tendons of the muscles attached to the margins of the femoral condyles to the posterior margins of the tibia and tibia collateral ligaments. The fibrous capsule does not extend above or over the patella. The suprapatellar bursa lies above the patella is the most complex synovial membrane in the body. The superior margin of the bursa extends to include the menisci and the fibrous capsule lining. There are multiply bursas that surround the joint in synovial fluid. One small sac-like bursa sits behind the knee at the junction of the groove on the surface of the meniscus and the tendon of the popliteus. If this small bursa communicates with the synovial fluid of the knee it is known as a Baker’s cyst and will fill with radiographic contrast during a knee arthrogram.

The knee is stabilized by the meniscus and four major ligaments. The medial collateral, also known as the tibial collateral ligament, starts at the medial condyle and
medial surface of the tibia and attaches to the medial epicondyle of the femur. The fibrous sheath blends with the medial collateral to join the joint capsule and medial meniscus. The medial collateral ligament helps to stabilize the knee in stresses outward and away from the body, i.e. bowlegged in flexion or extension. The lateral collateral ligament or the fibular collateral ligament starts at the lateral femoral epicondyle and ends at the fibular head. It lies independent of the fibrous capsule and protects the knee from inward stresses. The anterior cruciate ligament starts at the tibial plateau in front of the intercondylar eminence and ends at the posterior portion of the lateral femoral condyle. This ligament stabilizes the knee against any forward tibial movement. The posterior cruciate ligament comes from behind the intercondylar eminence and ends at the lateral aspect of medial femoral condyle. The posterior cruciate ligament protects the knee and the tibia from sliding backwards. The patellar ligament stabilizes the patella and acts as an aid to the quadriceps muscles (McKiness 245-246).

The menisci play an important role in joint mobility, stability and lubrication. The menisci are two cartilaginous semicircular pads that cushion the femur and tibial platform. Looking at them on edge, they are wedge shaped with a thick outer curve that...
thins medially. Together, the two menisci cover about two thirds of the articulating knee joint (Williams and Warwick 486). The lateral meniscus carries more of the joint load than the medial meniscus and is smaller in diameter, wider and thicker than the medial meniscus. The ends of the medial and lateral menisci are referred to as the horns and are identified as anterior or posterior of the respective menisci. The medial meniscus is more firmly attached to the capsule of the knee while the lateral meniscus is separated by ligaments and tendons. The ligament of Wrisberg is present in 60% of all knees and joins the lateral meniscus to the medial condyle of the femur (Berquist 334). The inner free borders of both menisci are thin, smooth and concave to fit the condyles of the femur.

The thick peripheral border is convex to help hold the femoral condyles on the tibial platform. The blood supplies to the menisci are from the middle genicular and the medial and lateral genicular arteries. The thick pink outer edge of the meniscus indicates a viable blood supply and is able to repair some types of tears, but the blood supply diminishes as the meniscus thins at the medial edge. The medial edges of the menisci appear white and are unable to repair any cartilaginous tears. Meniscus tears occur by movements that include rotating, quick shearing turns, or compression actions of stress. The medial meniscus is most often injured due to the firm attachment to the anterior intercondylar fossa of the tibia and the anterior and posterior attachment to the posterior intercondylar fossa of the
tibia. This firm attachment limits the medial menisci’s mobility and its ability to absorb stress. The exception to this is if an abnormality is present in the lateral meniscus called a discoid meniscus, which manifests itself as enlarged and thickened meniscus causing a wider joint space. It is believed that this condition is caused by repetitive movements (McKinnis 269). The most common of meniscus tears are vertical through the cartilage. The vertical tear can appear at the outer edge or throughout the menisci and are usually caused by stress on the cartilage. In older adults, degenerative tears are usually horizontal. Meniscus tears can occur at the peripheral edge or at any point vertically or horizontally throughout the cartilage. A tear that is vertical and extends along the radius of the cartilage within the body of the meniscus is referred to as a bucket handle tear.

Diagnosis of meniscus tears is difficult due to the radiolucent quality of the cartilage. Routine knee x-ray examinations are an anteroposterior position or AP and lateral position. It is the standard screening examination for the evaluation of the knee. If a meniscus tear is suspected the AP and lateral would rule out fractures and perhaps demonstrate joint effusion that demonstrates injury, but is inconclusive for diagnosis of meniscus tears. The AP knee is done supine with the central ray positioned 5-7° cephalad or towards the head at the apex of the patella. The lateral knee is done with the affected
knee on the table and in the lateral position flexed 25-30° and the central ray angled cephalad 5-7° at the medial aspect of the knee (McKinnis, 270). Knee arthrography in the joint may indicate a ligament tear or peripheral meniscal tear. After aspiration of fluid, 3-5 cc of a radiographic contrast, like Hypaque-M-60, Hexabrix or Renografin-M-60 with air into the joint space. The supine patient is steriley prepped on the radiographic table with the knee cushioned in a slightly flexed position and slightly internally rotated. A needle is introduced either medially or laterally into the joint space.

Fig. 5 AP right knee positioning and AP left knee radiograph (Greenspan 8.2)

Fig. 6 Lateral right knee positioning and lateral right knee radiograph (Greenspan 8.3)

the past decade was the definitive diagnostic exam for menisci and involved injecting an iodine radiographic contrast, like Hypaque-M-60, Hexabrix or Renografin-M-60 with air into the joint space. The supine patient is steriley prepped on the radiographic table with the knee cushioned in a slightly flexed position and slightly internally rotated. A needle is introduced either medially or laterally into the joint space.

Fig. 7 Injection of contrast for right knee arthrogram (Berquist 390)
inferior to the midline of the patella. Any joint effusion or fluid should be completely aspirated to prevent the diluting of the contrast media. The presence of blood or fluid in the joint may indicate a ligament tear, bleeding into the joint or peripheral meniscal tear. After aspiration of fluid, 3-5 cc's of contrast media is injected into the joint and then 20-40 ml of air. The contrast and air should easily inject into the joint without resistance indicating that the needle is properly placed in the joint. Air is commonly injected and takes several days to be absorbed. Air emboli are rare and CO₂ can be used, but is absorbed more quickly than air (Berquist 390). Single contrast arthrograms are done with just contrast media, but air offers a double contrast exam that defines the border of the meniscus from the synovial membranes of the femur and tibial platform. After introduction of the contrast agents into the joint space the needle is removed and the knee is exercised. The patient sits on the side of the table and the leg hangs over the side, extending and flexing the knee to mix the contrast agents evenly throughout the joint space. After briefly exercising the knee to distribute the contrast media and air, the knee is ready for the radiographic examination.

Concentration of the contrast media is optimal at the time of injection and will immediately start to be absorbed approximately 30 minutes after injection. Post injection, the patient will be prone on the table with the knee in a stress harness. Pressure will be applied to the lower leg to open up the joint space and allow contrast and air
to outline the meniscus. Because of the shape of the medial and lateral menisci, the knee must be stressed and rotated tangentially to examine the outer circumference of the medial and lateral menisci. The examination is done using fluoroscopy, taking 9 to 12 images of each meniscus. The patient is rotated slowly to examine the outer edge of the meniscus and applying pressure to the joint so that the contrast and air flows around the meniscus separating it from the femoral condyles and tibial platform. The views of the meniscus are wedge shaped profiles that demonstrate the tears by radiopaque lines running vertically or longitudinally in the meniscus.

Fig. 8. Positioning of the medial and lateral meniscus for a right knee arthrogram (Berquist 392)

Technique, positioning and stressing the knee are critical to get the meniscus in the correct position for diagnostic filming. Extravasations or leaking of the contrast media can obstruct collateral ligament tears or mask positive anatomy. Too much contrast media injected can pool in the inner condylar region giving a false positive for loose bodies. If the knee is worked too vigorously, the injected air will break up into bubbles and may simulate chondral bodies. The experience of the technologist is critical in stressing the knee so not to mimic tears by the buckling of the meniscus (Berquist 397). For diagnostic images, the patient must be able to rotate on the table and the knee must be loose enough for separation of the meniscus from the synovial membranes of the tibia and femur. Post images include AP position, lateral position and often notch or...
patellar views. These images are for evaluation of ligamental tears or cysts. Reaspiration to remove contrast media and air is usually not done. This is an invasive exam and the

**Fig. 9** Normal knee arthrogram medial meniscus (Berquist, 396)

**Fig. 10** Double contrast meniscus tears A. radial (oblique) tear of the posterior horn B. horizontal tear of the body C. bucket-handle tear of posterior horn D. bucket handle tear of the body with displaced fragment E. peripheral tear of posterior horn F. peripheral detachment of posterior horn. (Greenspan 8.28)
risks include infection, air emboli, pneumomediastinum, synovitis and contrast media allergic reaction (Berquist 399). Procedure time for preparation of the patient, injection and imaging is normally one hour including patient preparation, sterile procedure and films.

Magnetic resonance imaging, MRI, was developed in the 1970’s and was firmly established in hospitals and clinics by the mid 1990’s. It examines the patient by the use of magnetic fields and radiofrequencies. This modality is placed in the radiography department and is run by registered radiologic technologists. The process involves placing the body part of interest into a magnetic coil and inducing the magnetic spin orientation of hydrogen atoms, which in the body is primarily in the form of water. Once the body part is in a strong steady magnetic field, the protons are stimulated by radiowaves to change the spin orientation. The MRI unit then stops transmission of radiowaves and measures the electromagnetic transmission from the body as the protons relax into their normal state (History of MRI). The knee is placed in a magnetic gantry or coil that acts like an antenna for the radiowaves and a sequence of gradient echo sequences are used, primarily T1 and T2 weighted spin echo sequences. The T1 sequences are excellent for meniscus anatomy and synovial membranes. The T2 weighted sequence is used for the evaluation of ligaments and pathology. The knee is examined in the longitudinally, oblique and sagittal planes with 5 mm. slices and 18° separation (Berquist, 399). The electromagnetic radiation signal is then compiled into an image of the body part.

Where normal radiographs failed in cartilage and tissue imaging, MRI excels. Since our tissues have a large percentage of water and thus hydrogen atoms, MRI is
excellent for imaging tissue or cartilage as in the meniscus of the knee. Synovial membranes, meniscus cartilage and ligaments are deferential and visible on MRI. In radiography tissue, cartilage and ligaments all have about the same tissue density and are hard to differentiate on x-rays. Fat layers may separate some structures, but partial and complete tears of the meniscus and ligaments are very hard to distinguish. A standard MRI exam is 20 to 30 minutes in length, non invasive and gives greater detail eliminating the need for standard radiographic knee arthrograms.

The standard knee arthrogram procedures have been replaced by MRI. As MRI increased in magnetic strength new procedures were introduced. Once the magnets reached the strength of 1.5 Tesla, contrast media in the form of organic gadolinium is used for dynamic studies for knee, shoulder and hip arthrograms. The joint is injected in the radiology department with a solution of <1 cc of gadolinium and saline mixed with radiographic contrast with fluoroscopy for assurance that the joint space is injected. Then the patient is transferred to the MRI center and a series of scans are done in the axial, coronal, and sagittal positions to rule out capsular extravasations. This procedure takes approximately an hour, including the injection in the radiography department and the use of a fluoroscopy room and 30-40 minutes for the MRI procedure. Today, MRI is the exam of choice for meniscus tears (Berquist 401).
Total Hip Replacements

Total hip implants replace the ball and socket joint of the hip and are done on patients with certain types of hip fractures, severe arthritis, aseptic necrotic hips or congenital hip abnormalities that cause excessive wear (A Patient’s Guide). There are 352,000 hip fractures a year resulting from falls with women 2-3 times more likely to have fractures than men. In 2002, there were 192,221 total hip replacements performed in the United States (Falls). Women tend to have hip fractures due to post-menopausal loss.
of calcium causing the bones to be more brittle. One out of every seven women will fracture a hip in her lifetime and those reaching 90 will have a 50% chance of suffering a hip fracture (Falls). Calcium loss in the aged along with the weight bearing load at the femur hip junction can cause the hip to stress fracture in the area of the femoral neck or trochanter area of the femur. Often it is not known whether the fracture occurred first causing the patient to fall or whether the fall caused the fracture. Fractured hip evaluations are ordered in the radiology department usually as an AP pelvis, to include the entire pelvic frame, and a lateral view of the affected hip often in a frog leg position or taken as a cross table lateral. How a hip fractures will dictate how it will heal and be able to regain the stress of weight bearing.

Fig. 14 AP pelvis and radiograph (Berquist 7.2)

Fig. 15. Frog leg position for lateral hip and lateral hip x-ray (Greenspan 7.5)
Fractures are classified as intracapsular, that involve the femoral neck or head, or extracapsular fracture that involves the trochanter. The intracapsular fracture is subdivided into four categories of capital, subcapital, transcervical or basicervical. The extracapsular is divided into intertrochanteric or subtrochanteric. The ability of the body to heal a fracture depends on the age of the patient and the type of fracture. Indications for full hip replacements are fractures that weaken the integrity of the acetabulum, so the femoral head can not be supported or those in which the femoral neck has been fractured and compromises the blood flow to the head. Intracapsular fractures have a 15% to 35% chance of having blood flow complications causing ischemic or avascular necrosis and indicating a full hip replacement (Greenspan 7.17).
Fractures of the hip are classified by Garden staging of the femoral neck and head. The trabeculae of the spongy bone are composed of rod shaped cells that form the inner support of the bone. On the radiograph, they are demonstrated as groups of thin radiopaque lines that support the weight bearing bone. Garden staging observes three groups of trabeculae of the femur and of the acetabulum. The principle tensile trabeculae start from the lateral border of the greater trochanter, into the femoral neck and head ending inferiorly of the fovea. The principal or medial compressive trabeculae align with the trabeculae of the acetabulum and run vertically starting from the medial cortex of the neck and ending in the femoral head to form a triangle. The secondary or lateral
compressive trabeculae run from the lesser trochanter diffusing to the greater trochanter.

The area surrounded by trabeculae in the neck of the femur is called the Ward triangle (Greenspan 7.19). Where the fracture occurs can compromise the strength and stability of the weight bearing joint.

Fig. 18 Trabeculae of femoral head (Greenspan 7.19)

Fractures of the femur can be classified by two systems, the Pauwels and the Garden system. Both offer classifications to guide the orthopedist in evaluation of the stability of the fracture and the management and prognosis of the fracture. The Pauwels classification evaluates the femoral neck fracture and the angle of the fracture line to the horizontal plane in the post reduction AP radiograph. Fractures that occur at angles of 30 degrees and less across the femoral neck are considered stable and have a good prognosis for healing. A fracture that is 30-70 ° from horizontal across the femoral neck is not as stable and have a poorer diagnosis. Those fractures that are 70 ° or more and are almost vertical slanting almost parallel with the intertrochanter line have the worse diagnosis for healing for the angle is too steep for stability. The more vertical the fracture, the worse
the stability and the greater the probability of the bone not healing.

Fig. 19 Pauwels classification of intracapsular fractures (Greenspan 7.29)

Garden staging divides fractures into two major categories: intracapsular and extracapsular and is based on how the principal or medial compressive trabeculae have been displaced. Stage I is an incomplete subcapital fracture. This fracture is an impacted femoral head fracture that has not separated the head from the neck and the femoral shaft is twisted outward away from the midline. The medial trabeculae have an angle of greater than 180°. This fracture line is near horizontal and is considered a stable fracture with usually no complications in healing. Stage II is a complete subcapital fracture without displacement. The femoral head is completely fractured away from the neck of the femur but is not displaced. If the medial trabeculae are at an angle of 160° from the femoral shaft, it is a stable fracture and will heal without complications. Stage III is a complete fracture of the femoral head from the femoral neck and is displaced. The femoral head is rotated, abducted and turned inward. If the medial trabeculae are not lined up with the trabeculae of the shaft or the acetabulum, then the fracture is unstable the prognosis is not good. Stage IV is complete subcapital fracture with full displacement. The femoral shaft is rotated outward and superiorly displaced anteriorly to the femoral head. The head of
the femur is completely separated from the femur, yet is still in the normal position in the acetabulum. The medial trabeculae of the femoral head are still aligned with the trabeculae of the acetabulum. This type of fracture is unstable and the prognosis is poor (Greenspan 1.19-7.20). Staging of femoral fractures is important in the assessment of patients since one out of every four hip fractures results in death within 12 months of the fracture. (Falls) One of the complications in recovery is a loss of blood supply to the femoral head, especially in Stage III and IV fractures causing death to the bone or osteonecrosis.

![Garden staging of subcapital femoral fractures](image)

Fig. 20 Garden staging of subcapital femoral fractures (Greenspan, 7.20)
Blood loss to the bone will cause death of that part and will lead to the deterioration of the synovial membrane and loss of bony mass. The incidence of osteonecrosis in femoral neck fractures is high, due to the anatomy of the hip joint. The ball shaped femoral head sits in the cup shaped acetabulum of the pelvic bone. A capsule surrounds the joint starting from the acetabulum surrounding the head and neck of the femur to the intertrochanteric line. The blood supply to the head of the femur is supplied by the femoral artery via a ring of vessels at the base of the neck of the femur. The vessels reach upward from the intertrochanteric line into the neck and reaching into the head. Very few blood vessels supply the femoral head from the ligamentum teres which is the ligament that comes from the fovea or end of the femoral head to the acetabulum.

![Fig. 21 Blood supply to the proximal femur (Greenspan 7.28)](image)

notch. The artery that travels with the ligament adds very little to the femoral head and may disappear in adulthood. Therefore if a femoral neck fracture occurs, the possibility of disruption of blood flow to the head is possible and must be considered in the prognosis of the patient. Type III and IV fractures where the head of the femur has been rotated and displaced are susceptible to a loss of the blood flow. In 24% of femoral neck
fractures, the blood flow has been compromised and a complete hip replacement must be considered. If the blood flow is disrupted, then the femoral head dies on the average of 9-12 months post fracture. Radiographic changes can occur as late as three years post fracture with a marked radiopaque density on the radiograph. (Berquist 278-279)

Vascular integrity of the femoral head can be evaluated in several ways. At the time of the fracture an AP and lateral view of the hip is negative; the exam may be repeated at a later time if the patient still experiences pain. Continued pain may suggest a nuclear medicine scan to be done with Technetium 99 to assess the blood flow to the femoral head, or MRI can assess the blood flow to the femoral head. One of the earliest

![Fig. 22 Humeral crescent sign](McKinnis 235)

![Fig. 23 Bilateral femoral head crescent signs](McKinnis 234)

signs of structural collapse of the femoral head is a crescent sign that can appear as early as four weeks post fracture. The crescent sign is demonstrated as a radiolucent line on the AP or lateral hip that follows the border of the articulating surface of the femoral head.
and represents the collapse of the necrotic bone. This is a diagnostic sign in both shoulders and hips.

A radiopaque fluffy sclerosis is seen in the joint cavity as the body attempts to reossify the bone. As avascular necrosis advances, the joint space has narrowed and the head of the femur becomes flattened and is seen as more dense because of the body attempts to revascularize the bone. Structural collapse of the femoral head due to avascular necrosis is cause for a complete hip replacement.

Fig. 24. Avascular necrosis and severely demineralized femoral head. The fluffy sclerosis is a reossification attempt. Note the narrow joint space. (McKinnis, 236)

Severe arthritis that has deteriorated the acetabulum and the femoral head is another criterion for complete hip replacement. Osteoarthritis is the most common degenerative joint disease the affects the hip joint (McKinnis 230). On the AP and lateral hip radiograph there are three characteristics of osteoarthritis or degenerative joint disease. The joint space will be narrowed between the femoral head and acetabulum due to the loss of proteoglycan from the articular cartilage matrix. This causes a loss of elasticity and of the collagen fibrils support system that makes the articular cartilage
more prone to joint friction and accelerates the splitting of the cartilaginous surface. The body cannot repair the cartilage fast enough and this causes the joint space to narrow.

The second response in degenerative bone disease is the loss of cushioning resulting in sclerotic subchondral bone. This loss of cartilage in the exposed areas of the contact area of the femoral head or subchondral bone becomes more dense or sclerotic. This area appears more radiopaque or dense on radiographs.

The third response is osteophyte formation. This is a response to repair the articular cartilage at the outer margins of the joint. Osteophytosis are bony growths in the shape of bone spurs, thickened edges or abnormal bone growth. In weight bearing joints, excessive pressure causes microfractures in the trabeculae of the subchondral bone allowing synovial fluid into the spongy bone causing cyst (McKinnis 57-58).

Osteoarthritis can occur with no preexisting conditions, however several pre-existing medical conditions can lead to osteoarthritis. Paget’s disease, epiphyseal disorders,

Fig 25 Left Classic signs of degenerative joint disease A. narrowed joint space with superior migration of femoral head B. osteophyte formation at the joint margins C. Sclerosis, increased density of the subchondral bone D. acetubular protrusion. The acetabulum is bulging due to the migration of the femoral head. Right total hip replacement (McKinnis 231)
congenital dislocation, avascular necrosis or other types of inflammatory arthritis can lead to osteoarthritis and eventually to total hip replacements (McKinnis 230).

Indications for total hip replacements from degenerative joint disease are based on the comfort of the patient and radiographic evidence. First indication for total hip replacement is if the hip causes excessive pain during ordinary activities as to restrict work and recreation. The second indication is if the pain cannot be relieved by the use of anti-inflammatory medicine or the use of a cane and therefore prevents one from achieving normal activities. The last indication for a total hip replacement is if the patient has significant stiffness of the hip therefore restricting activity or if the radiograph shows advancing arthritis (Total Hip).

Standard preparation for total hip replacement is AP and lateral hip radiographs before surgery to match the best fitting prosthesis. The prosthesis consists of two pieces. The metal stem fits into the medullary canal of the femur with the ball end acting like the femoral head that fits into the socket like component into the acetabulum. The acetabulum component has a metal outside with a plastic inner component that allows the ball type

Fig. 26 A prosthesis with a metal-backed, high-density plastic socket and ball with stem (Virtual Hospital)
head of the stem to rotate. The orthopedic surgeon first makes an 8 to 10 inch incision over the hip joint and separates the muscle and ligaments to the hip joint. Once in the hip joint, the femoral head is dislocated from the acetabulum and cut off at the distal part of the femoral neck. The acetabulum is then cut and shaped to fit the cup shaped component of the prosthesis. The medullary canal of the femur is reamed out to fit the stem part of the femur component. Once the stem is placed in the medullary canal the ball is positioned in the acetabulum. A final radiograph is taken in surgery to confirm proper positioning.

The prosthesis is made of titanium or cobalt/chromium-based alloys or can be made up of ceramic materials such as aluminum oxide or zirconium oxide that can be cemented or uncemented. Materials for prostheses must be biocompatible to prevent rejection. They must be resistant to corrosion and be able to maintain their shape over many years. They must be able to withstand weight bearing loads and be able to function in their role without breakage. Most of all, prosthesis must be manufactured within quality control standards and at a reasonable cost.

The head is highly polished for smooth rotation in the acetabulum prosthesis. The total weight for both components is between 14 and 18 ounces. In uncemented prostheses, the shaft and back of acetabulum is rough so that new bone growth can attach itself to the implant. The stem is wedge shaped so that the fit in the medullary canal forms a tight bond. A tight bond between the prosthesis and bone is essential since it takes 6 to 12 weeks for the bone to attach itself to the implant. In cemented prostheses, the cement used is an acrylic polymer, polymethylmethacrylate (PMMA). Cemented prostheses have faster recovery time, allowing the patient to put full weight on the
prosthesis quickly after surgery and therefore having quicker recovery (Falls). However cemented prosthesis have a 50% failure rate due to the cement’s cracking in the joint and loosening the stem (Galante 230). The cement can form small debris particles and cause an inflammatory response which in turn can cause osteolysis which removes bone from around the implant causing further loosening. Cemented prostheses are usually recommended for patients over 60 while more active patients have uncemented prostheses (Falls).

Total hip replacement surgery requires a 4-10 days in the hospital and 3-4 months for total recovery. Total hip replacement patients will return to the radiography department for AP and lateral hip radiographs if the prosthesis loosens. The complications are blood loss and muscle damage from the incision site. There is a chance of infection deep at the joint site or at the incision site and a chance of thrombophlebitis. The prosthesis may become dislocated or loosen in the femoral shaft or in the acetabulum. The average lifetime of hip replacements is 13.2 years, and 74% will need revision or surgery to replace the complete prosthesis due to wear of the synthetic components or loosening due to cement loss or femoral cracking (McGrory).

Microplasty minimally invasive technique is a new surgical technique to reduce the trauma, pain, and recovery time. A small incision site of 2-3 inches over the greater trochanter is large enough with the new development of surgical tools to replace the hip joint. The new surgical tools enable the surgeon to make more precise cuts, replacing the damaged bone joint with less trauma to the surrounding muscle. This new surgical procedure for hip replacements reduces the trauma for the patient and offers a quicker recovery. Patients have smaller incisions, less blood loss, less muscle damage and less
postoperative pain. Hospital stays are 1-3 days long with studies showing the potential for shorter recovery. This procedure is less invasive and is guided by fluoroscopy during surgery offering a new surgical procedure for technologists. Patients avoid the days of imposed rest and are able to return to normal activity with less pain and better results. This new surgical technique is also being applied to knees and shoulders. (Biomet)

New opportunities are opening for CT computer based analysis for preoperative planning of hip replacement parts. Finding the right sized hip component usually involves using a template over the top of the AP pelvic radiograph. Studies have shown when using a Muller hip prosthesis (a cemented prosthesis) that 92% of the femoral component and 90% of the acetabular components were of one size step or less. Similar studies with uncemented components show a one step size or less in 85% of the stems and 96% of the acetabulum sockets. However one size step can make a difference in hip replacements and improper fitting can cause cement cracking or the cracking of the femoral shaft. Software is available to aid the orthopedic surgeon in measuring the exact inner diameter of the medullary canal and to use computerized images of the different sizes and shapes of prostheses for an accurate fit.

In a study done with 29 patients, an AP pelvis and a CT scan with helical scanner (Hispeed, GE Medical Systems, Milwaukee, WI) were done. All cases were considered difficult clinical cases. The conditions included congenital dysplasia (65.6%), primary arthrosis (20.7%), post traumatic arthrosis (6.9%), secondary arthrosis and Perthes' disease (3.4%) and revision surgery of two septic cementless stems (3.4%). All patients used the AnCAFt cementless prosthesis. In all cases the surgery was done with the HipOp planning software and then 15 days post surgery a radiographic template was applied
and reviewed by two other surgeons. This was a blind study and patient identity was removed. Each patient was reviewed by the three surgeons by the two different methods. Results showed that in using the template the correct stem size was accurate in 34% of the cases and 41% for the acetabulum. The Hip-Op system was accurate for 52% for the stem and 66% for the acetabulum (Viceconti, 371-376). The advantage of better fitting implants increases the probability of the implant lasting longer and increased patient satisfaction. Hip-Op is just one of several CT orthopedic planning programs that are available for surgeons.

Biomet of Warsaw, IN offers an advanced computer service for patient matched implants. There are patients that can not fit in standard sized implants. These patient populations may have had destructive bone disease caused by tumors and have destroyed the structure of the acetabulum so it can no longer hold the femoral head. They may have had a previous hip implant with acetabulum bone loss and can no longer fit a standard acetabulum implant. Patients with short stature such as dwarfism or who are excessively tall have hips that are more severely stressed than the average population, and with age can wear through the acetabulum socket and need a custom made implant. Biomet has designs and manufactures approximately 1200 hip prostheses per year for patients that do not fit standard implants.

To construct a three dimensional image to build a new acetabulum Biomet requires an uncompressed CT scan from the iliac crest to mid femur. They need the patient to be in the AP position with the feet inverted and the femur of interest parallel to the horizontal plane of the table. CT slices of 2.5 mm or 3 mm should be taken with two femoral condyle slices to show anteversion. Once Biomet has the scan, their radiologic
technologist compiles the CT scan into a three dimensional image. The technologist then progresses through the scan, slice by slice and builds the implant. The prosthesis is a three flanged acetabulum cup that will be anchored to the pelvis with screws. Before the tri-flange can be built, the technologist must remove any existing cement from the CT scan to measure the original bone. Slice by slice, a model of the pelvis is done and then a tri-flange prototype is built. It is this prototype that is sent to the orthopedic surgeon for any revisions and then returned to Biomet. Any changes will be marked with a marker to indicate if the surgeon wishes to remove any bone or the attachment sites of the tri-flange. A final model is constructed to reflect a match to the patient’s dimensions and shipped to the surgeon for the procedure. The turn-around time from start to finished product is three to four weeks. At this time, Biomet is the only facility to offer this custom design prosthesis. It is not profitable, but the demand is strong, and as new software is developed to offer faster turn around time, this is a new application for radiologic technologists.

Fig. 27 Step 1 and 2 in designing Biomet’s patient-matched implant
Fig. 28 Procedural steps for Biomet’s patient-matched implant

Step 3
Anatomical model used to create an implant prototype

Step 4
Hemi-pelvis model showing tri-flange cup implant

Step 5
Post surgical implantation of a tri-flange cup

Fig. 29 Final results for Biomet’s patient-matched implant
Rotator Cuff Tears

Rotator cuff tears in the shoulder are painful and more common than once believed. A recent study on cadavers indicated that 70% of people over the age of 80 and 30% of the population under 70 endure some degree of rotator cuff tear in their lifetime. (Cluett) The rotator cuff is made of four muscle and tendon groups that surround the humeral head as it sits in the glenoid fossa of the scapula. The structurally weak joint offers a wide range of adduction, abduction and circumduction that enables us to manipulate and control our hands. The shoulder is strengthened by muscle and tendon groups and the fibrous capsule surrounding it. The fibrous capsule attaches to the outer circumference of the glenoid cavity, includes the origin of the bicep and then attaches to the anatomical neck of the humerus. The humeral head and glenoid fossa are coated in a hyaline membrane and are joined loosely with a separation of 2-3 cm considered within normal range. The rotator cuff consists of the subscapularis (anteriorly), supraspinatus (superiorly), infraspinatus (posterosuperiorly) and teres minor (posteriorly) muscles. Together with the fibrous capsule, they make up the rotator cuff, which strengthens the glenohumeral joint and encloses synovial fluid. The bursae of the shoulder are sacs of synovial fluid to help diffuse the friction of muscles and tendons and are numerous, with up to eight in the shoulder (Williams & Warwick 456-458).
Communication with the bursa is often an indicator of a tear in a muscle or rotator cuff which can be demonstrated by several methods in the radiography department.

![Posterior view of right shoulder](image)

**Fig. 31** Posterior view of right shoulder (Greenspan, 5.3)

![A. normal rotator cuff, supraspinatus muscle intact B. Complete tear of supraspinatus muscle and communication with bursae. C. Communication between subacromial-subdeltoid bursae and glenohumeral cavity filling with contrast media.](image)

**Fig. 32.** A. normal rotator cuff, supraspinatus muscle intact B. Complete tear of supraspinatus muscle and communication with bursae. C. Communication between subacromial-subdeltoid bursae and glenohumeral cavity filling with contrast media. (Greenspan 5.20)
Rotator cuff tears, complete or partial, most often occur in the supraspinatus muscle, 1 cm from the insertion into the greater tuberosity of the humerus (Greenspan 5.19). Rotator cuff tears usually have a history of trauma and are grouped by R.J. Neiaser into five groups.

1. Trauma without fracture dislocation
2. Anterior dislocation
3. Dislocation with avulsion of the greater tuberosity
4. Chronic pain without history of trauma
5. Avulsion of the greater tuberosity”

(qtd in. Berquist 614)

Patient symptoms can include pain, loss of range of motion, (especially abduction) and decreased strength. Yet, some patients have no symptoms. A routine examination will include radiographs of internal and external rotation of the shoulder to...
demonstrate an AP

Fig. 34 Routine normal AP external rotation shoulder x-ray (McKinnis 332-333)

Fig. 35. Routine normal AP internal rotation shoulder x-ray (McKinnis 334-335)

and lateral view. Standard radiographs can demonstrate chronic rotator cuff tears by a narrowing of the acromiohumeral space to less than 6 mm. (normal joint space is 1 cm.).

The humerus appears elevated with atrophy and flattening of the greater tuberosity due to the lack of pressure of an intact supraspinatus tendon and there is erosion to the inferior aspect of the acromion. (Greenspan 5.19). Cystic erosion might be present on the greater
tuberosity at the site of the supraspinatus or a "double tuberosity" which could be an ossified or calcified stump of the supraspinatus muscle. However it takes time for a chronic condition to appear on a radiograph and another radiograph must be done at a later time for more conclusive testing.

**Fig. 36 Left** Normal external rotation view with cystic erosion open arrow **Right**: arthrogram with incomplete thickness tear in rotator cuff (Berquist, 609)

**Fig. 37** Double tuberosity with chronic rotator cuff tear and subluxation with cartilaginous calcification open arrow (Berquist, 609)

Shoulder arthrography is the examination of the joint capsule and was once considered the "gold standard" for the suspected rotator cuff tears. (Greenspan 5.20). Shoulder arthrograms also demonstrate adhesive capsulitis, bicep tendon abnormalities, articular cartilage, glenoid labrum and the synovium. (Berquist 620) The procedure starts with the patient supine on the table with the arm externally rotated. The patient is externally prepped with a povidone-iodine
solution at the area of the glenohumeral joint. A syringe of 1% lidocaine is used to mark the site of injection at the glenohumeral joint below the coracoid in the distal third of the joint space. The surface and tissues are infused with 1% lidocaine and a 25 gauge needle is inserted at the medial humeral head to avoid the glenoid labrum into the intra-articular space. In single contrast studies, 6-10 ml of a diatrizoate melamine (Hypaque-M-60) is injected. Contrast injection should be observed under fluoroscopy to see if the contrast flows away from the needle indicating proper positioning in the joint space.

Accumulating contrast at the needle tip indicates extravasations of the contrast into tissue and improper needle placement. If a double contrast exam is being done, then 4 ml of diatrizoate melamine contrast media is injected along with 10-15 cc of air, depending on the size of the joint capsule. Observation of the contrast injection is important because leakage of the contrast media into the subacromial bursa can pinpoint the exact site of the rotator cuff tear (Berquist 611). The needle is then removed and the patient exercised to distribute the air and/or contrast media for any potential bursa leaks. Imaging sequences vary from institution to institution but often include AP, lateral shoulder with internal and external rotation images and bicipital groove. The procedure from preparation of the patient to final radiograph series is approximately 35-45 minutes.

Fig. 38 A. correct needle placement B. normal shoulder arthrogram C. anatomy (Greenspan 5.10)
MRI is a noninvasive approach for rotator cuff tears and other abnormalities. The advantage of MRI is the ability to examine the soft tissues of the shoulder in coronal, sagittal and axial views, with T1 and T2 weighted spin-echo cycles. The first sequence will be axial with 3 mm. slices with 1.5 mm skip slices from the axillary region to the superior portion of the acromioclavicular joint. These two pulse sequences are usually enough to visualize the synovial fluid and rotator cuff. Sagittal views are often done to visualize the undersurface of the AC joint and to check for impingement which is where the supraspinatus tendon and subacromial bursa are chronically trapped between the humeral head or the anterior acromion. C.S. Neer II has “divided rotator cuff disease into three stages. The initial stage (Stage I) consists of edema or hemorrhage in the rotator cuff, specifically the supraspinatus tendon. During stage II there is progression of the inflammatory stage to a more fibrotic process. The final stage, Stage III, results in a tear in the rotator cuff” (Berquist 628). The importance of being able to identify inflammation is that it is treatable and can be reversed. Shoulder arthrograms would be read as normal while MRI can detect an increased signal from T-1 indicating edema, inflammation or hemorrhage. The thirty minute MRI exam can also accurately assess the size of the tear when compared to surgical measurements, the specific tendons involved, musculature atrophy and the quality of the torn edge (Greenspan 5.20-5.21). MRI, along with comparative radiographs, adds to the doctor’s ability to accurately access and plan for the patient’s diagnosis and treatment.
Fig. 39 Axial, coronal, and sagittal planes (Berquist 627)

Fig. 40 Axial, sagittal and coronal MRI views demonstrating a large cuff tear arrows (Berquist, 629)
The Role of Tissue Engineering in Radiology

The first knee meniscus repair was over 100 years ago (Forster & Aster 323). Today, meniscus repair is in the hands of the orthopedic surgeon with little intervention from radiology. Radiology evaluates the condition, marks the results of the surgery, and records the post surgery status, but has very little intervention in the repair of meniscus. By the 1930’s the role of the meniscus was well documented. Its primary role was to protect the articular membranes of the femoral head and tibial platform and to distribute the weight bearing load of the knee. However it was discovered that removing damage meniscus relieved the pain at first but would cause degenerative change to the joint.

King’s research in 1936 on canine models demonstrated that the proportion of meniscus removed was directly proportional to the damage done in degenerative change. King also discovered if artificial tears induced in the canines were extended into the vascular part of the meniscus that the tear would heal. In 1948, Fairbanks performed complete and partial meniscectomy and noted arthritic radiologic changes. Since then degenerative changes have been noted even with partial meniscectomy. In 1969, arthroscopy was first used and follow up studies still showed that the removal of any part of the meniscus will eventually cause degenerative change (Forster & Aster 323). Further research was done to try to preserve the meniscus as a whole.

Meniscus repair to preserve the complete meniscus can be done by suturing. Repair depends on the location and vascularity of the meniscus tear. The meniscus has a blood supply that lies in the thicker, peripheral edge and then dissipates as the meniscus thins towards the inner edge. Peripheral tears which are stable meaning the edges of the tear are not displaced and lie next to each other within an area of vascularity, defined as
red/red zone, have a good chance of self repair. The blood vessels in a peripheral tear that are at the edge of the tear and are through the thickest part of the meniscus and are torn <5 mm and displaced by <3 mm, do not require surgery and are likely to heal. Tears that are longitudinal in the red/red zone or red/white zones and are stable also have a chance to heal. Radial, flap or tears in the white/white zone have little success in healing. Larger tears where fibrin glue has been used have little success in healing. Age does not seem to influence the outcome of meniscus repair so much as the size of the tear and whether the tear is stable or tends to be chronic (Forster & Aster 324).

Attempts have been made to repair meniscus tears that are bucket handle by suturing. To surgically remove the inner loose segment of a bucket tear often represents a large surface area where bone will not be cushioned. The bone on bone contact will eventually result in wearing away the synovial membrane and an earlier occurrence of degenerative arthritic damage. The success of suturing repairs depends on the size of the tear and whether the anterior cruciate ligament (ACL) is intact. If the ACL is being reconstructed the meniscus will have a better chance of healing due to haemarthrosis or bleeding into the joint. The increased serum factors have shown to help in the healing of the meniscus (Forster & Aster 325). The meniscus must be prepared by roughing the edges of the tear and the synovium around the tear at the time of arthroscopy surgery. Abrading the area is thought to increase the vascularity and improve the outcome of repair along, occasionally, with the use fibrin clot to help in revascularization. Under arthroscopy, the tear is sutured by the orthopedic surgeon (Forster & Aster 326).
There are several ways to mend the meniscus by suturing. How strong the suturing depends on the size of tear and the method. The vertical mattress stitch is considered the strongest. The use of the horizontal stitch has the same strength as the use of the Biofix meniscal arrow, T fix by Biostinger. Suturing needs to hold the edges of the meniscus together long enough for the tear to heal. This can be different for each patient, depending on the blood flow at the tear site and severity of the tear. The strength of the suturing therefore is an unknown factor since the suturing only needs to be strong enough to allow the tear to heal (Forster & Aster 326).

In clinical studies post suturing repair, the highest rate of success is when the suturing occurs along with ACL reconstruction. Evaluation of the tear within a two year
period showed that 17-37% have incomplete healing while 7-50% do not heal at all. Complications from surgery can involve saphenous neuropathy, arthrofibrosis, septic arthritis, and peroneal neuropathy. Implants like the meniscal arrow have been known to break, causing cyst formation, chondral damage and occasional posterior knee pain (Forster & Aster 326). Despite the potential for post surgery complications, studies did show a slight improvement in preventing degenerative arthritic damage. In studies where they compared both knees for degenerative arthritic damage the repaired meniscus knee had 8% articular cartilage damage compared to the control knee that showed 3% articular cartilage damage (Forster & Aster 326). Considering that meniscus tears are occurring in younger populations with long term degenerative arthritic damage, this is an alternative to a meniscectomy or removal of the damaged part of the meniscus.

New tissue engineering techniques being developed may change radiology’s role in meniscus repair. Biological substitutes for structural tissues have been a continuous challenge for decades. There has been some success in tissue engineering with temporary skin substitute for burn patients and diabetic ulcers. However, recent development in tissue regeneration has given hope to medical problems from meniscus repair to heart damage. The need for new tissue growth for repair is complex, with the need to restore the structure and maintain the function of the organ. The problems addressed are how to establish a “reliable and abundant source of cells, find optimal ways to promote cell proliferation and tissue formation, learn how to regulate cell behavior and function on synthetic scaffolds, maximize the mechanical functional properties of the resulting tissues, and create new scaffolding or templating material for cells.” (Anseth HHMI)

Each of these key steps is extensive in scope, but the last step is important in radiology
because it has potential impact for future examinations in the radiography field.

Extensive discussion on tissue engineering is beyond the scope of this paper but a brief overview of the mechanical material to hold cell cultures for tissue implantation will follow.

Cell research is expanding into all areas of cell implantation ranging from nerves, muscles, bones, tendons and cartilage. The mechanical support for the new growth is complex in that they must offer a nurturing site plus stay where it is placed. If the muscle or cartilage is torn, the repair cells must stay at the torn site and not migrate elsewhere in the body. New biomaterial had to be developed to provide a three dimensional cell matrix for tissue regeneration. Researchers were looking for a material that would have permeability, strength, biocompatibility and high water content so nutrients and wastes were highly exchangeable. They were looking for a material that would fit into the human body that could bend with the tissue and adhere to the surrounding tissue, whether it be muscle, tendon or cartilage. Hydrogels, which were discovered in the 1960’s, fit many of those characteristics. Hydrogels are water-soluble macromolecules that have a tissue-like elasticity and can be easily integrated into tissue parts. They are based on “natural polymers, including alginates, collagen, gelatin, and agarose” and “also synthetic polymers such as poly(hydroxyethyl methacrylate), poly (ethylene oxide), and poly(acrylonitrile-sodium methallyle sulfonate)” (Nuttelman 217). These would form the matrix for the migration of cells or the seeding of cells, but they also need an adhesion protein with the matrix so as to stick to the injured site. Cell adhesion proteins are needed to bridge the matrix to the human cells. The proteins used are fibronectin, laminin and vitronectin.
The cell matrix and adhesive proteins also need the ability to be absorbed by the body. The material needs to maintain structural integrity, yet degrade with water at different rates. The material should degrade from the outside in and compensate for the different concentration in the body. The matrix is made up of different polymer molecules that will be absorbed at a rate from one month to one year. To maintain the shape and integrity of the polymer once it is in the body, a light-sensitive material was added, that will solidify when exposed to light. The matrix is then placed at the damaged site encouraging migration of cells, as in bone cells, or is seeded with chondrocytes that secrete cartilage. It is the chondrocytes that have been seeded in matrix structures that have shown promising repair of torn meniscus in goats. Along with meniscus repairs is the regrowth of the hyaline membrane of the femur and tibia. Such research could eliminate degenerative bone disease and help arthritis sufferers. It is the hope of researchers someday, nerve stem cells will be infused with matrix structures for the regeneration of severed nerves and spinal cords (Anseth, 2001). Already research has been able to grow “human-shaped phalanges consisting of multiple joints that have been formed in athymic mice by seeding chondrocytes and tenocytes in a biodegradable polymer scaffold and wrapped with the periosteum” (Alhadlaq et al, 912) Tissue engineering is in its infancy and what can be done is still unknown.

Radiology’s role in tissue engineering will be one of assessment and evaluation of matrix integrity. MRI will be able to document the progress from extent of damage of the tissue at the injured site to the placement of the matrix through the stages of absorption of the matrix as new cells grow. MRI will also be able to assess the extent of the original tissue damage to lay a map for matrix placement. The ability of MRI to take
coronal, sagittal and axial views will give a three dimensional layout for precise placement of the matrix. MRI will also be able to chronicle long term assessment of new tissue engineering techniques.

The Impact of Technology on Radiologic Technologists

Often my radiologic technology students question the future of their jobs. They are immersed in learning the technology of the present and are constantly bombarded with new technology. It is not uncommon for them in the course of their two years of clinical studies to see new equipment installed in the department on a monthly basis. It may range from new image processors, digital mobile equipment to new CT or MRI scanners. It is clear to them that after their training and passing of their national registry exam for diagnostic radiography by the American Registry of Radiologic Technologists (ARRT) that their training is not done. Their fear is that their level of training will not keep up with technology and that their jobs will be phased out. What they do not understand is that radiology has been changing rapidly for the last three decades. In the last three decades CT, Ultrasound, MRI, and PET have all been commercialized and made available for patient examinations. Because of new technologies, radiographers will continuously undergo training for equipment development in diagnostic radiography or go on to specialize in one of the many modalities of radiography. With that technology is the need for specialized education that may involve in site hospital training or structured formal training at education sites. For those that pick special procedures, cardiovascular studies, ultrasound, CT, MRI, or PET scanning, it will mean another year of training. Nuclear medicine and radiation therapy may involve one to two years of
training. Radiography today means an ever changing climate of new technology and the need for better trained technologists.

The changes in technology have been discussed as we have seen how three exams, the evaluation of the meniscus of the knee, total hip replacements and rotator cuff tears have been influenced by new technology. In the last 25 years, CT, Ultrasound, MRI and PET scanning are increasing by 9% per year (Rothenberg 3). This increase reflects also a demand for radiologic technologists in these specialized modalities. Hospitals are adding the new services of CT, Ultrasound, MRI and PET, ultimately to meet the demands of patients. Patients equate new technology with better and faster service and are more satisfied that they are getting the best care. A Blue Cross & Blue Shield review of cross-national surveys found that Americans believe that having the "most advanced medical technology is absolutely essential." They "believe that modern medicine can cure almost any illness for people who have access to the most advanced technology and treatment" (qtd. in Rothenberg 2). This type of thinking puts additional pressure on hospitals to have CT, Ultrasound, MRI and PET scanners. Hospitals want to be able to offer such services to maintain and increase patient revenues. However, the question remains, does it improve on the quality of service?

New technology does not just offer another way to perform a test, but a better way. New technology offers more information in a safer and less invasive way. The knee arthrogram was an invasive examination with the potential of infection via needle injection with the possible risk of contrast media reactions. However, MRI offers excellent visualization of the cartilage and ligaments without the risk of an invasive procedure. In the Michiana area, Memorial Hospital, St. Joseph’s Regional Medical
Center and Elkhart General Hospital have not performed knee arthrograms for five years (Interview results, March 2005). Hip arthrograms are no longer performed at the three sites with CT and MRI scanning taking the majority of those exams. At the sites polled, none yet are using Hip-Op to measure the correct size of prostheses. Surgeons are using AP and lateral hip radiographs for prosthesis measurement. MRI is also used for evaluation of hip vascularization and evaluation of synovial membrane integrity.

Memorial Hospital and St. Joseph Regional Medical Center do not perform shoulder arthrograms anymore but use the special procedure rooms for injection of the contrast of gadolinium and then transfer the patient for MRI studies 2-3 times a week. The Elkhart General Hospital rarely does shoulder arthrograms, but does inject gadolinium for MRI studies on a regular weekly basis (Interview results, March 2005). MRI, CT and Ultrasound examinations do give more conclusive results than invasive diagnostic exams and are the exams of choice over arthrograms.

If the results from these new technologies are more conclusive and safer than radiographic arthrogram then the concern becomes the random ordering from referring physicians for excessive body scans. This concern was addressed in May of 2003 by the American College of Radiology (ACR) which recommended guidelines to referring physicians to prevent random scanning that could affect the patient’s future health from excessive radiation and cost. The ACR was concerned that needless scans would cause anxiety over potential health issues without patient or family history. For example, it is normal for arthritic change to occur as we age. If these changes were noted and the patient had no symptoms, is the scan warranted? It was also the ACR’s concern that a diagnosis that has no symptoms could increase patient anxiety and create an excessive
cost for follow-up examinations and treatments. New clinical guidelines were recommended by the ACR for the proper prescription and use of diagnostic imaging in hope of reducing unnecessary exams (Rothenberg 2).

The pressure for maintaining or improving hospital revenues, patient satisfaction or physicians' referrals have shown an increase in CT, MRI, Ultrasound and PET examinations not just in large hospitals but also in smaller rural hospitals. In a 2001 survey, by Blue Cross & Blue Shield, almost 100% of all hospitals have an ultrasound machine, 3,779 or 79.9% have one or more CT scanners, 2,412 or 51.0% have MRI scanners and 242-300, less than 10% have PET scanners (some hospitals share PET scanners that are mobile, rotating days at designated hospitals). Hospitals, clinics and outpatient sites all feel the pressure to have the most advanced equipment and have engaged in a technology race for having the best in equipment.

The cost of the technology machine race is passed down to the patient with higher health cost. Ultrasound machines typically cost $250,000 and are used to monitor fetal development, evaluation of blood flow in arteries, blood clots in veins and evaluation of soft tissue organs with expected growth in sales from 2000-2005 increasing at a 5.8% rate. Most hospitals, including Memorial Hospital, St. Joseph Regional Medical Center South Bend and Elkhart General Hospital, offer day time service with on call service for ultrasound in the evening, night and weekends. CT scanners are approximately $1.2 million and hospitals may have more than one in the central radiography department and/or scanners at outpatient sites and emergency room. CT's can evaluate soft tissue organs and bone with the ability to access bleeds. Their projected growth is 8.9% a year from 2000-2005 with 24 hour service at most hospitals. All three area hospital sites offer
involves passing a national certification test (All Allied). It is predicted that by 2010, United States will require 75,000 additional technologists to fill the positions for general radiography, CT, MRI, Ultrasound and cardiovascular studies. Registered schools and facilities will produce 51,000 new technologists. This will still leave a deficit of 24,000 technologists or 24% to run the new technology. Schools and facilities are trying to increase enrollment but are often limited by space and availability of clinical sites. In 2003, the ASRT reports that the highest number of students 9,627, sat for national registry board exam. When compared to 7,149 students that took the exam in 2000, it represents an increase of 35%. This is the largest increase in 7 years; however the Bureau of Labor Statistics is still projecting a shortage due to three factors (Silver). First is the increase in new technology and the increase of equipment at hospital and clinical sites. Facilities are buying equipment based on patient demands and competition for patients. Duplication of exam sites is not based on number of exams done in the area but the pressure of patients wanting the newest technology for diagnosis. Second is the aging population of technologists and retirement with the current number of schools and facilities being unable to produce the technologists that will be needed. In a 2002 survey, 79% of the responding radiologic technology schools stated that they had enrolled the capacity number of students. Third is that a large percentage of the population in the U.S. is composed of post war baby boomers that are aging. Ceela McElveny, director of public relations for the American Society for Radiologic Technologists (ARST) states, “just when the need for health care services will be skyrocketing, a larger percentage of RT’s (Radiologic Technolgists) will be retiring” (qtd in Silver). Studies have shown that Americans over the age of 65 have 250 diagnosticitc
images done per 100 diagnostic imaging procedures done per year compared to 130 diagnostic imaging procedures per 100 to the population under 65. As post WWII baby boomers approach 65, more tests will be done, increasing the need for more equipment and technologists (Silver).

In conclusion, increasing equipment technology that eliminates procedural exams, i.e. arthrograms, will not negatively impact the number of job positions for radiologic technologists. Examinations may be eliminated, as in the knee arthrograms, or altered to fit new protocols for new procedures, as in the joint injection of gadolinium for MRI studies, but this will not impact the total work load in the radiography department. The continued specialization in the field of radiologic technology and patient demand for the newest technology will have a positive impact for radiographers. There is a nationwide shortage of radiologic technologists and that trend will continue for several more years. New technology provides new job descriptions that require more specialized training but also offer new opportunities in the job market. The future for radiologic technology will offer more specialized fields and wider opportunity for employment.

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Curriculum Vitae

Diane Bradley-Kantor is an associate faculty in the Radiography department in the Division of Nursing and Health Professions at Indiana University South Bend. She is currently teaching for the 2004-2005 year, Physics Applied to Radiography and Computer Applications in the Medical Field to junior radiography students, and Principles II and Pathology to senior radiography students. In her eight years at IUSB, she has also taught Orientation to Radiology, Radiologic Principles I, Radiologic Principles III, Junior Clinical Positioning Lab, Senior Clinical Positioning Lab, Venipucture and Pharmacology, Topics in Radiography and was Clinical Coordinator. In 2001, Diane was awarded a $2000 IUSB grant for the purchase of a cross-sectional anatomical model. From 1999-2001, she served as a member of the STOP committee, assisted in the JCERT recertification process for radiography and has volunteered to talk at various schools to promote radiological studies.

Diane received her B.S at the University of Minnesota in Biology and Public Health and an Associate Degree in Radiologic Technology at the University of Minnesota School Of Radiologic Technology in 1977. She received her HEW proficiency exam for Clinical Laboratory Technology in 1978. Diane taught Computer Literacy and Radiation Biology at the School of Radiologic Technology at Memorial hospital from 1981-1988. At that time she worked at Memorial Hospital in Special Procedure performing peripheral arteriograms, cerebral arteriogram, angioplasties, biliary tube placements, myelograms and shoulder, knee and hip arthrograms. In 1984, she was named Memorial Hospital’s “Radiologic Technologist of the Year” and in 1986 was named the School of Radiologic Technology “Teacher of the Year”.

She currently is living in Granger, IN with her husband, Jeffrey, their two sons and their dog, Jumper.