Spring 1998

Magnetic Resonance Imaging, Arthrography, and Ultrasound in Diagnosing Rotator Cuff Tears: An Evaluation of Agreement

Andrea Solsona

MAGNETIC RESONANCE IMAGING, ARTHROGRAPHY, AND ULTRASOUND IN DIAGNOSING ROTATOR CUFF TEARS: AN EVALUATION OF AGREEMENT

Andrea Solsona

Magnetic Resonance Imaging, Arthrography,

and Ultrasound in Diagnosing Rotator Cuff Tears

An Evaluation of Agreement

by

Andrea Solsona

A Thesis Proposal Submitted to the Faculty

of the College of Graduate Studies

at Georgia Southern University

in Partial Fulfillment of the

Requirements of the Degree of

Master of Science

in the Department of Health and Kinesiology

Statesboro, Georgia

May 1998

Magnetic Resonance Imaging, Arthrography,

and Ultrasound in Diagnosing Rotator Cuff Tears:

An Evaluation of Agreement

by

Andrea Solsona

James L. McMillan, Chairperson

Don Ray Connell

W. Kent Guion

A. Barry Joyner

G. Lane Van Tassell
Associate Vice President for Academic Affairs
and Dean of Graduate Studies

5/25/98
Date

DEDICATION

To Mom and Dad.............................Thanks for everything!

ACKNOWLEDGMENTS

I would like to thank the staff of the Department of Health and Kinesiology at Georgia Southern University for their assistance, in particular Dr. McMillan, Dr. Guion, and Dr. Joyner. They made this study possible.

I would like to send a HUGE thanks to Dr. Don Ray Connell at Statesboro Imaging Center. Without his generous donation of resources, time, and guidance, I could not have done this project.

I want to thank Dr. Buxton for getting me through the vital stages of this paper (not to mention graduate school). I will never forget you and what you have done for me.

Lastly, thank you Aaron and Dennis. As friends and co-workers, you supported me and allowed me time to conduct this study. I enjoyed being on an island with you.

ABSTRACT

Eleven patients who had a clinical suspicion of a rotator cuff tear were referred for a magnetic resonance imaging exam, an arthrographic exam or both. Additionally, all patients received a diagnostic ultrasound exam. The results of the imaging studies were compared to surgical or clinical diagnosis. Arthrography had 100% positive predictive value (PPV), negative predictive value (NPV), accuracy, specificity, and sensitivity. Magnetic resonance imaging had 100% PPV, 60% NPV, 78% accuracy, 100% specificity, and 67% sensitivity. Ultrasound had 80% PPV, 50% NPV, 64% accuracy, 75% specificity, and 57% sensitivity. Based on these results, taking into consideration the national average costs of each study, no definitive recommendation can be made regarding the "best" diagnostic study. However, it is suggested that a strong clinical suspicion should be followed by a diagnostic ultrasound exam, the least expensive of the three procedures. Only if the ultrasound differs from the clinical suspicion should a more expensive, perhaps more invasive, procedure be performed.

TABLE OF CONTENTS

TITLE PAGE	i
APPROVAL PAGE	ii
DEDICATION	iii
ACKNOWLEDGMENTS	iv
ABSTRACT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	viii
LIST OF FIGURES	ix
INTRODUCTION	1
METHODS	5
RESULTS	8
DISCUSSION	10
REFERENCES	15
TABLES	22
FIGURES	27
APPENDIX A	33
Delimitations	34
Limitations	34

Assumptions 34

Significance of the Study 34

APPENDIX B 35

Definitions 36

APPENDIX C 37

Raw Data 38

LIST OF TABLES

Table 1.	Ultrasound versus surgery in previous studies
Table 2.	Arthrography versus surgery in previous studies
Table 3.	MRI versus surgery in previous studies
Table 4.	Results for current study

LIST OF FIGURES

Figure 1. Positive predictive value for the current study

Figure 2. Negative predictive value for the current study

Figure 3. Accuracy for the current study

Figure 4. Specificity for the current study

Figure 5. Sensitivity for the current study

INTRODUCTION

Shoulder pain ranks behind neck and back pain as the orthopaedic complaint most encountered by physicians.[1] The Dutch General Practitioner Committee found shoulder pain to be the primary complaint in 25 out of 1000 patients and accounted for 1 in every 10 cases in orthopaedic clinics.[2,3] This is especially true in middle-aged and older patients as a chronic condition or, less often, as the result of a traumatic event in a younger person.[4] Although these injuries may be the result of damage to a variety of structures, often it is due to damage to the rotator cuff complex.

The rotator cuff complex is comprised of the subscapularis, the supraspinatus, the infraspinatus, and the teres minor. The supraspinatus, infraspinatus, and teres minor all originate on the posterior surface of the scapula and insert on the greater tubercle of the humerus. The subscapularis originates on the anterior surface of the scapula and inserts on the lesser tubercle. Together, these are the primary muscles involved in abduction, internal rotation, and external rotation, as well as stabilization of the humeral head into the glenoid fossa[5] Injuries to the rotator cuff are traditionally identified first by clinical exam then by a follow-up radiologic examination. The clinical exam involves manual muscle testing and special tests such as the Empty Can Test.[6] Following a symptomatic clinical exam, radiologic evaluation is used to validate the clinical diagnosis prior to surgery.

In 1938, contrast arthrography was introduced to aid in the evaluation of shoulder injuries including rotator cuff pathology, adhesive capsulitis, and capsular disruptions.[7] Arthrography involves injection of a contrast agent into the shoulder joint and follow-up observation via a fluoroscope. A positive arthrogram is one in which the contrast agent is observed leaking out of the joint space into the surrounding tissue.[8] The accuracy of single and double-contrast arthrograms in diagnosing rotator cuff tears has been reported as high as 98-99%.[7,9] Although the arthrogram has long been the standard in rotator cuff diagnosis, it must be noted that it does have disadvantages. It is an invasive procedure and, as such, carries risk of neurovascular injuries and infection. [10,11] Additionally, patients undergo radiation exposure, have a risk of allergic reaction to the iodine based contrast agent, and also report pain with the procedure.[10,11] It can also be time consuming and expensive. [10,11]

In 1977, the use of diagnostic ultrasound was introduced to aid in diagnosing rotator cuff tears. The diagnostic procedure was presented at the annual meeting of the American Institute of Ultrasound in Medicine by Victor Mayer. [12] In the middle 1980s, ultrasound technology progressed to a level that allowed readable images of the rotator cuff and potential tears to be clearly observed. [13,14,15,16] Ultrasound is able to visualize the rotator cuff by using sound waves that are beyond the audible range, ideally 7-10 MHZ. [17] Short, pulsed ultrasound waves are sent into the tissue and reflect back to the transducer. These vibrations are then sent to a monitor via a computer in the form of images. [18] Diagnostic ultrasound has the advantage of being less expensive, fast, safe, and noninvasive. [15,19] Results in previous studies of diagnostic ultrasound have been mixed, however, and range from a sensitivity of 63% and a specificity of 50%[20] to a sensitivity of 100% and a specificity of 94%.[21,22] Sensitivity is the probability that the imaging procedure declares those shoulders positive where a rotator cuff tear exists. Specificity is the probability that the imaging procedure declares those shoulders negative where a rotator cuff tear does not exist.[23]

In recent years, Magnetic Resonance Imaging (MRI) has become increasingly preferred in the diagnosis of rotator cuff tears.[24] MRI uses a magnet to line up hydrogen nuclei in the body. Radio waves are transmitted into a specific anatomical location and re-emitted and received by an antenna. This antenna sends the reflected radio waves to a computer which interprets and organizes the different signals into tissues and structures in a cross-sectional view.[25] First developed in 1943, MR technology was not used to view body parts until 1973 and has gained steady popularity since that time.[18] MRI is a non-invasive procedure and provides a cross-sectional view not available with ultrasound or arthrography. However, the large expense associated with MRI studies coupled with the time involved, its contraindication for use in patients with metal implants or pacemakers, and the expertise required to both perform and interpret MRI testing have been criticized in its use as a first-line diagnostic tool.[27] MRI has been reported to demonstrate from 67%[27] to 100% sensitivity[28,29] and 89%[30] to 100% specificity[20] in the diagnosis of rotator cuff tears.

With all the diagnostic possibilities available, physicians often develop a preference for specific diagnostic studies. Additionally, the cost of each procedure should be considered. Nationwide average costs charged by radiologists and hospitals as reported by Blue Cross/Blue Shield are $925.00 per procedure for an upper extremity MRI, $500.00 for an upper extremity arthrogram with contrast material, and $220.00 for a diagnostic ultrasound of an extremity. [31] (These costs include both the cost of the procedure as well as the cost of interpretation.) Of further importance is the fact that Medicare and many Health Maintenance Organizations (HMO)have set allowances for each modality. The Medicare allowance for MRI is $470.00, $230.00 for an arthrogram, and $80.00 for an ultrasound. [31] The average Managed Care Allowance for an MRI is $600.00, an arthrogram is $285.00, and $96.00 for an ultrasound. [31] The difference between the insurance coverage and the cost of the procedure must, therefore, be covered by the patient or absorbed by the healthcare system.

During a time of rising health care costs, fiscal restraint, and self insurance as well as the time, safety issues, convenience, and operator experience required for each procedure, health care professionals need to carefully consider each factor before prescribing a particular diagnostic study. Therefore, the purpose of this study was to discover if relationships exist between MRI, arthrogram, ultrasound, and surgical findings in diagnosing rotator cuff tears. Secondly, a cost to benefit recommendation for first-line diagnostic studies for rotator cuff tears will be made based on the results.

METHODS

Subjects

This was a retrospective study of 11 subjects comprised of 6 male and 5 female adults. The patients ranged in age from 19 to 87, with an average age of 56. All patients were referred by local physicians to the Statesboro Imaging Center with a clinical suspicion of a rotator cuff tear. Patient one had a chief complaint of pain with no injury. Patient two had pain with gradual onset, no injury. Patient three had shoulder pain, no acute injury. Patient four fell on an outstretched arm and suffered subsequent shoulder pain. Patients five and six had shoulder pain with limited motion with no acute injury. Patient seven had a chief complaint of burning pain in the right shoulder. Patients eight, nine, and ten had an unknown mechanism of injury, if any, and suffered from rotator cuff pain. Patient eleven suffered shoulder pain as a result of playing softball over a period of time.

Each patient was prescribed to undergo either an MRI, an arthrogram, or an ultrasound. In addition to this prescribed test, each patient also received one or both of the remaining studies (MRI, arthrogram or ultrasound)on the same visit. All tests were performed by a Board Certified Radiologist or Radiologic Technician and interpreted by Board Certified Radiologists. One radiologist interpreted the MRI and arthrogram results and another read the ultrasound results. All tests were interpreted without knowledge of the results of the other radiologic tests. All results were reported to the prescribing physician with the non-prescribed tests being reported in an addendum. After receiving informed consent, the patient's chart was reviewed to obtain radiological and/or ultrasound results. The patient's physician was contacted to obtain surgical results.

Equipment and Procedures

MRI

The MRI studies were performed on a Shimadzu MRI unit (Kyoto, Japan). A flexible coil was used around the affected shoulder. A 0.5 Telsa magnet was used.

Arthrogram

Single contrast arthrograms using a 51% iopamidol injection were performed. The shoulder was viewed under a real-time fluoroscope during adduction, abduction, flexion, internal rotation, and external rotation. Still pictures were taken during each range of motion. If no contrast was obviously leaking, the patient was instructed to exercise by taking the shoulder through all ranges of motion for 5-10 minutes. The still pictures were repeated and again evaluated for an abnormality.

Ultrasound

The ultrasound was performed with a 7.5 MHZ transducer in the upright, sitting position. The shoulder was hyperextended and slightly internally rotated as recommended by Crass et al.[31] The shoulder was observed dynamically for irregularities, and static pictures were obtained and evaluated.

Data Analysis

The frequency of test results were recorded and described. From these results, positive predictive value, negative predictive value, specificity, sensitivity, and accuracy were found using the respective formulas.

RESULTS

The results of each diagnostic test are shown in Appendix B. The data analysis of all tests are shown in Table 4. All eleven subjects received an ultrasound exam. In addition, patient one had an arthrogram and surgery. Patient two had an MRI but no surgery. Patients three, four, and five had an MRI and surgery. Patient six had an arthrogram and surgery. Patient seven had an MRI and no surgery. Patients eight and nine had an MRI and surgery. Patient ten had an MRI, an arthrogram, and surgery. Patient eleven had an MRI and no surgery. Overall, nine patients received an MRI, three received an arthrogram, and seven underwent surgery. The four patients who did not have surgery were clinically found to have no rotator cuff tear.

The MRI studies agreed with surgery in four of the six patients who underwent both MRI and surgery. The two MRI studies that disagreed had a negative MRI and a positive surgical result. The four in agreement had positive MRI results and positive surgical results. This resulted in a 100% positive predictive value. The negative predictive value of MRI in this study was 60%. Sensitivity was 67%, specificity was 100%, and accuracy was 78%.

Two of the three patients who had an arthrogram had surgical evaluations. Both patients who had surgery had outcomes that agreed with the positive arthrogram results. The patient who did not have surgery and who was diagnosed clinically as having no rotator cuff tear had a negative arthrogram. Overall, the three arthrograms had a positive and negative predictive value of 100%. Specificity, sensitivity, and accuracy were also 100%.

Of the eleven patients who had diagnostic ultrasound testing, seven had surgery. Of the shoulders that were surgically evaluated, four positive ultrasound results agreed with four positive surgical results, including two which had negative MRI studies. Of the remaining three surgical patients, the ultrasound studies showed no tear. Surgery on the same three patients revealed rotator cuff tears. Positive predictive value was 80% and negative predictive value was 50%. Sensitivity was 57%, specificity was 75%, and accuracy was 64%.

DISCUSSION

Shoulder pain is the primary complaint in 10% of all visits to orthopaedic surgeons. With this prevalence, it is somewhat surprising that there is no agreement on the best pre-operative evaluative tool to diagnose a possible rotator cuff tear. Currently, magnetic resonance imaging, arthrogram, and ultrasound are being used. This study compared the three to see which test might be the most appropriate.

Due to the small number of subjects, any test with outcomes different from surgical findings makes a large difference in results. The results of this study were similar to other studies of this size. [38] It should be noted that many studies with excellent results for a given test used a large number of subjects. Crass et al. [35] conducted one study with more than 500 subjects and had an accuracy rate of 97% for ultrasound. The current study was limited in the number of subjects available.

Arthrogram

Arthrogram, the smallest test group, had the best results of all tests, 100%. Once the "gold standard" in rotator cuff diagnosis, it has been criticized for being invasive and uncomfortable, if not painful. Mack et al. [15] and Burk et al.[20] also found good results with arthrography, finding an accuracy of 98% and 94%, specificity of 90% and 100%, and sensitivity of 100% and 92%. The concerns with arthrography are valid. The procedure can be painful, there is a possibility of allergic reaction to the iodine, and it can be time consuming. However, the results it has in diagnosing rotator cuff tears may outweigh these negatives.

MRI

MRI, the current trend in imaging procedures, had mixed results in this study. The positive predictive value was very good. The negative predictive value, though, was 60%. The patients with a negative MRI who followed-up with surgery due to clinical findings were found to indeed have a rotator cuff tear. Like Wang et al., [41] MRI testing had a good positive predictive value. Hodler et al.[48] and Wnorowski et al.,[30] in contrast, found poor positive predictive values. The negative predictive value in this test was less than ideal. Previous studies have found the opposite to be true. [30] Wnorowski et al. [30] found a negative predictive value of 81%, much higher than our value. They found the negative predictive value to be the strength of MRI. Overall, previous MRI results have been mixed. Accuracies of MRI testing have ranged from 71%[30] to 100%[50] with 39 and 30 subjects respectively. The current study found an accuracy of 78%. Higher numbers of subjects fall in the midrange, as did Farley et al. [51] with 102 subjects and an accuracy of 86%. Previous sensitivities have ranged from 71% [30] to 100% [28]. This study found a sensitivity of 67%, which was lower than previous values.

The specificity found, however, was 100%, the same value found by Burk et al. [20] in 1989. Although it is the most technological advanced of the three techniques investigated, MRI still has room for improvement. In this study, for example, five negative MRI results were found. Two of those findings were challenged surgically. A rotator cuff tear was present in both cases. The remaining three negative findings were not confirmed nor disputed since surgery was not performed; however, clinically they were found to have no tear.

Ultrasound

Ultrasound had results somewhat lower than some to previous studies. This may be due to the small number of subjects used in this study. Kurol et al. [40] had a positive predictive value of 60% while vanMoppes et al. [42] and Sonnabend [49] each had a 96% positive predictive value. This study had a positive predictive value of 80%. Negative predictive values have ranged from 73% [43] to 98% [45]. This study had a negative predictive value of 50%. Sensitivity in this study was 57% while specificity was 75%. The sensitivity values were higher than 48% found by Kurol et al. [40] but lower than the values found by Crass [22] and Hodler, [33] both with sensitivities of 100%. The specificity values were similar to values found by Brandt [36] and Soble. [37] Some previous values were much higher, 100%, in a study by Mack et al. [15] and some were lower, such as 65% found by Pattee and Snyder. [47] Reasons for these extremes may include experience of the technologist performing the test, [15] experience of the radiologist reading the test, [15] blockages of the rotator cuff by other shoulder structures, [16] and underside tears missed on the ultrasound image. [16] Although results were midrange, it should be again pointed out the advantages of ultrasound. Ultrasound is non-invasive, quick to perform, and safe. [15,19] Compared to MRI and arthrogram, these characteristics must be considered.

Costs

Another important issue to be discussed is the expense of each diagnostic procedure. Although this study cannot make a clear-cut recommendation based on cost, the following must be considered. Ultrasound is the least expensive of the three with a national average of $220. [31] In the middle range of cost is arthrography, the best results in this study, at an average of $500 each. [31] The most expensive test is MRI. The average cost of an MRI is $925.[31] Of the nine MRI tests performed, six had follow-up surgery. Two of the six were patients whose MRI results came out negative and, because of clinical suspicion, had surgery anyway. Only three of nine people avoided surgery due, in-part, to MRI results. However, it should be considered that if any of those three patients had continued clinical suspicions, they, too, might have had surgery. In those cases, the patient incurs an additional $925 MRI in addition to surgery. Based on the false negative findings of this study alone, perhaps strong clinical findings with a less expensive diagnostic procedure should be considered preoperatively.

The results of this study did not clear up the debate on the best pre-operative diagnostic tool to be used in diagnosing rotator cuff tears. Nor was this study able to make a clear-cut cost recommendation regarding diagnostic testing of rotator cuff tears. However, this study showed that MRI, thought to be the diagnostic tool of the future, did have false negatives on the only negative shoulders that underwent surgery. That finding warrants notice and consideration, especially when one considers the expense of such an exam. Arthrogram, once the standard of diagnosis, should not yet be discounted, regardless of its concerns. Ultrasound, coupled with a strong clinical finding, may be an appropriate, cost-effective means to confirm suspicions. Many previous authors [4, 15, 16, 19, 22, 33, 34, 35, 37, 41, 43, 44, 45, 47, 48, 49, 54, 55, 56] strongly suggest ultrasound as a first-line diagnostic tool due to its safety and cost. They suggest that only if ultrasound does not confirm clinical suspicions then another, more-expensive, perhaps more invasive, imaging procedure be done. Regardless of the decision made, patients and physicians must together evaluate each case and its clinical findings and systematically decide the most cost-effective method of pre-operative diagnosis of rotator cuff tears.

Future research in this area should include a large number of subjects. As seen in this study, a small group of subjects can cause a large variance in results with only one or two result discrepancies. Additionally, researchers should use a cost-to-benefit formula which combines results and cost. This can be an objective tool used by physicians and patients when imaging procedures are necessary to determine the best procedure, both medically and financially, for each case.

REFERENCES

1. Uri DS. MR Imaging of shoulder impingement and rotator cuff disease. Radiol Clin North Am. 1997; 35: 77-96.
2. Bakker JF, de Jongh L. Schouderklachten, NHG, Huisarts en Wetenschap. 1990; 33: 196-202.
3. Hedtmann A, Fett H. Atlas und Lehrbuch der Schultersonographie. Bücherei des Orthopäden Band 52 Enke Verlag 1988.
4. Paavolainen P, Ahovuo J. Ultrasonography and arthrography in the diagnosis of tears of the rotator cuff. J Bone Joint Surg. 1994; 76-A: 335-340.
5. Gray, H. Gray's Anatomy, 15th ed. New York, NY: Barnes and Noble, 1995.
6. Miniaci A, Salonen D. Rotator cuff evaluation: Imaging and diagnosis. Orthop Clin North Am. 1997; 28: 43-58.
7. Mink JH, Harris E, Rappaport M. Rotator cuff tears: Evaluation using double-contrast shoulder arthrography. Radiology. 1985; 157: 621-623.
8. Kaye JJ, Schneider R. Arthrography. New York, NY: Appleton-Century-Crofts; 1979: 137-157.
9. Braunstein EM, O'Connor G. Double-contrast arthrotomography of the shoulder. J Bone Joint Surg. 1982; 64-A: 192-195.

10. Hall FM, Rosenthal DI, Goldberg RP, Wyshak R. Morbidity from shoulder arthrography: Etiology, incidence, and prevention. American Journal of Radiology. 1981; 136: 59-62.

11. Hall FM, Goldberg RP, Wyshak G, Kilcoyne RF. Shoulder arthrography: Comparison of morbidity after use of various contrast media. Radiology. 1985; 154: 339-341.

12. Mayer V. Ultrasonography of the rotator cuff [letter]. J Ultrasound Med. 1985; 4: 608.

13. Middleton WD, Edelstein G, Reinus WR, Melson GL, Murphy WA. Ultrasound of the rotator cuff: Technique and normal appearance. J Ultrasound Med. 1984; 3: 549-551.

14. Crass JR, Craig EV, Thompson RD, Feinberg SB. Ultrasonography of the rotator cuff: surgical correlation. J Clin Ultrasound. 1984; 12: 487-492.

15. Mack LA, Matsen FA, Kilcoyne RF, Davies PK, Sickler ME. Ultrasound evaluation of the rotator cuff. Radiology. 1985; 157: 205-209.

16. Middleton WD, Reinus WR, Melson GL, Totty WG, Murphy WA. Pitfalls of rotator cuff sonography. AJR. 1986; 146: 555-560.

17. Mack LA, Matsen FA III, Kilcoyne RF, Davies PK, Sickler ME. US evaluation of the rotator cuff. Radiology. 1985; 157: 205-209.

18. Ballinger PW. Merrill's Atlas of Radiographic Positions and Radiologic Procedures. St Louis, MO: Mosby-Year Book Inc; 1991.

19. Olive RJ Jr, Marsh HO. Ultrasonography of rotator cuff tears. Clin Orthop. 1992; 282: 110-113.

20. Burk DL, Karasick D, Kurtz AB, Mitchell DG, Rifkin MD, Miller CL, Levy DW, Fenlin JM, Bartolozzi AR. AJR. 1989; 153: 87-92.

21. Bretzke CA, Crass JR, Craig EV. Ultrasonography of the rotator cuff: normal and pathologic anatomy. Invest Radiol. 1985; 20: 311-315.

22. Crass JR, Craig EV, Bretzke C, Feinberg SB. Ultrasonography of the rotator cuff. Radiographics. 1985; 5: 941-953.

23. Kuzma JW. Basic Statistics for Health Sciences. 3rd Edition. Mountain View, California: Mayfield Publishing Company, 1998; 128-139.

24. Prendergast N, Rafii M. Magnetic resonance imaging of the shoulder joint. Curr Opin Radiol. 1992; 4: 70-76.

25. Bontrager KL. Textbook of Radiographic Positioning and Related Anatomy. St Louis, MO: Mosby-Year Book Inc; 1993.

26. Stiles RG, Otte MT. Imaging of the shoulder. Radiology. 1993; 188: 603-613.

27. Nelson MC, Leather GP, Nirschl RP, Pettrone FA, Freedman MT. Evaluation of the painful shoulder: A prospective comparison of magnetic resonance imaging, computerized tomographic arthrography, ultrasonography, and operative findings. J Bone Joint Surg. 1991; 73: 707-716.

28. Iannotti JP, Zlatkin MB, Esterhai JL, Kressel HY, Dalinka MK, Spindler KP. Magnetic resonance imaging of the shoulder. J Bone Joint Surg. 1991; 73-A: 17-29.

29. Wang YM, Shih TT, Jiang CC, Su CT, Huang KM, Hang YS, Liu TK. Magnetic resonance imaging of rotator cuff lesions. J Formos Med Assoc. 1994; 93: 234-239.

30. Wnorowski DC, Levinsohn EM, Chamberlain BC, McAndrew DL. Magnetic resonance imaging assessment of the rotator cuff: Is it really accurate? Arthroscopy. 1997; 13: 710-719.

31. Spahn, J. Conversation. Blue Cross/Blue Shield. February 3, 1998.

32. Crass JR, Craig EV, Feinberg SB. The hyperextended internal rotation view in rotator cuff ultrasonography. J Clin Ultrasound. 1987; 15: 416-420.

33. Hodler J, Fretz CJ, Terrier F, et al. Rotator cuff tears: correlation of sonographic and surgical findings. Radiology. 1988; 169: 791-794.

34. Furtschegger A, Resch H. Value of ultrasonography in preoperative diagnosis of rotator cuff tears and postoperative follow-up. Europ J Radiol 1988; 8: 69-75.

35. Crass JR, Craig EV, Feinberg SB. Ultrasonography of rotator cuff tears: A review of 500 diagnostic studies. J Clin Ultrasound. 1988; 16: 313-327.

36. Brandt TD, Cardone BW, Grant TH, Post M, Weiss CA. Rotator cuff sonography: A reassessment. Radiology. 1989; 173: 323-327.

37. Soble MG, Kaye AD, Guay RC. Rotator cuff tear: Clinical experience with sonographic detection. Radiology. 1989; 173: 319-321.

38. Vick CW, Bell SA. Rotator cuff tears: Diagnosis with sonography. AJR. 1990; 154: 121-123.

39. Nelson MC, Leather GP, Nirschl RP, Pettrone FA, Freedman MT. Evaluation of the painful shoulder. A prospective comparison of magnetic resonance imagine, computerized tomographic arthrography, ultrasonography, and operative findings. J Bone Joint Surg. 1991; 73-A: 707-716.

40. Kurol M, Rahme H, Hilding S. Sonography for diagnosis of rotator cuff tear: Comparison with observations at surgery in 58 shoulders. Acta Orthop Scand. 1991; 62: 465-467.

41. Weiner SN, Seitz WH Jr. Sonography of the shoulder in patients with tears of the rotator cuff: Accuracy and value for selective surgical options. AJR. 1993; 160: 103-107.

42. Brenneke SL, Morgan CJ. Evaluation of ultrasonography as a diagnostic technique in the assessment of rotator cuff tendon tears. Am J Sports Med. 1992; 20: 287-289.

43. van Moppes FI, Veldkamp O, Roorda J. Role of shoulder ultrasonography in the evaluation of the painful shoulder. Eur J Radiol. 1995; 19: 142-146.

44. Farin PU, Jaroma H. Acute traumatic tears of the rotator cuff: Value of sonography. Radiology. 1995; 197: 269-273.

45. van Holsbeeck MT, Kolowich PA, Eyler WR, Craig JG, Shirazi KK, Habra GK, Vanderschueren GM, Bouffard JA. US depiction of partial-thickness tear of the rotator cuff. Radiology. 1995; 197: 443-446.

46. Farin PU, Kaukanen E, Jaroma H, Väätäinen U, Miettinen H, Soimakallio S. Size and site of rotator cuff tear. Invest Radiol. 1996; 31: 387-394.

47. Pattee GA, Snyder SJ. Sonographic evaluation of the rotator cuff: Correlation with arthroscopy. Arthroscopy. 1988; 4: 15-20.

48. Hodler J, Terrier B, von Schulthess GK, Fuchs WA. MRI and sonography of the shoulder. Clin Radiol. 1991; 43: 323-327.

49. Sonnabend DH, Hughes JS, Giuffre BM, Farrell R. Aust N Z J Surg. 1997; 67: 630-633.

50. D'Erme M, De Cupis V, De Maria M, Barbiera F, Maceroni P, Lasagni MP. Echography, magnetic resonance and double-contrast arthrography of the rotator cuff. A prospective study in 30 patients. Radiol Med (Torino). 1993; 86: 72-80.

51. Farley TE, Neumann CH, Steinbach LS, Jahnke AJ, Petersen SS. Full-thickness tears of the rotator cuff of the shoulder: Diagnosis with MR Imaging. AJR. 1992; 158: 347-351.

52. Gagey N, Desmoineaux P, Gagey O, Idy-Peretti I, Mazas F. Contribution of MRI to the preoperative evaluation of rotator cuff tears. Rev Chir Orthop Reparatrice Appar Mot. 1991; 77: 521-529.

53. Yeu K, Jiang CC, Shih TT. Correlation between MRI and operative findings of the rotator cuff tear. J Formos Med Assoc. 1994; 93: 134-139.

54. Drakeford MK, Quinn MJ, Simpson SL, Pettine KA. A comparative study of ultrasonography and arthrography in evaluation of the rotator cuff. Clin. Orthop. 1990; 253: 118-122.

55. Chiou HJ, Hsu CC, Chou YH, Tiu CM, Jim YF, Wu JJ, Chang CY. Sonographic signs of complete rotator cuff tears. Chin Med J (Taipei). 1996; 58: 428-434.

56. Bachmann GF, Melzer C, Heinrichs CM, Mohring B, Rominger MB. Diagnosis of rotator cuff lesions: comparison of US and MRI on 38 joint specimens. Eur Radiol. 1997; 7: 192-197.

TABLES

TABLE 1 ULTRASOUND VERSUS SURGERY IN PREVIOUS STUDIES

STUDY	# OF SUB.	(+) PRED	(-) PRED	ACCURACY	SPECIFICITY	SENSITIVITY
Mack [15]	47			94%	100%	91%
Crass [22]	122			97%	94%	100%
Hodler [33]	51			92%	95%	100%
Furtschegger[34]	406					91%
Crass [35]	500			90%	90%	90%
Burk [20]	10				50%	63%
Brandt [36]					76%	87%
Soble [37]	30				73%	93%
Vick [38]	2			85%	93%	67%
Nelson [39]						
FT				84%	92%	60%
PT				59%	75%	36%
Kurol [40]		60%	80%	70%	85%	48%
Wiener [41]	225			92%		
Brenneke [42]					82%	78%
Paavolainen[4]		95%	75%	84%	95%	74%
vanMoppes [43]		96%	73%		91%	86%
Farin [44]	184	94%	87%		93%	89%
vanHolsbeeck[45]	52	82%	98%		94%	93%
Farin [46]						
FT				90%		
PT				80%		
Pattee[47]	52	82%		73%	65%	77%
Hodler [48]	24	93%				
Sonnabend[49]	17	96%				

TABLE 2 ARTHROGRAPHY VERSUS SURGERY IN PREVIOUS STUDIES

STUDY	# OF SUB	(+) PRED	(-) PRED	ACCURACY	SPECIFICITY	SENSITIVITY
Mack [15]	41			98%	90%	100%
Crass [22]	122			75%	97%	61%
Crass [35]	500			82%	89%	76%
Burk [20]	16			94%	100%	92%
Soble [37]	30				100%	87%
Paavolainen[4]				94%	95%	93%
Farin[36]						
FT				90%		
PT				70%		
D'Erme [50]	30			91%		

TABLE 3 MRI VERSUS SURGERY IN PREVIOUS STUDIES

STUDY	# OF SUB	(+) PRED	(-) PRED	ACCURACY	SPECIFICITY	SENSITIVITY
Burk [20]	16			94%	100%	92%
Nelson [39]						
FT				90%	93%	86%
PT				76%	89%	67%
Iannotti [28]	106				95%	100%
Farley [51]	102			86%		
D'Erme [50]	30			100%		
Gagey [52]	38				94%	93%
Hodler [48]	24	67%				
Wnorowski[30]	39	59%	81%	71%	71%	71%
Wang [29]	40	92%		95%	89%	100%
Yeu [53]	10			80%		89%

TABLE 4 RESULTS FOR CURRENT STUDY

TEST	(+) PRED.	(-) PRED	ACCURACY	SPECIFICITY	SENSITIVITY
MRI	100%	60%	78%	100%	67%
ARTHROGRAM	100%	100%	100%	100%	100%
ULTRASOUND	80%	50%	64%	75%	57%

FIGURES

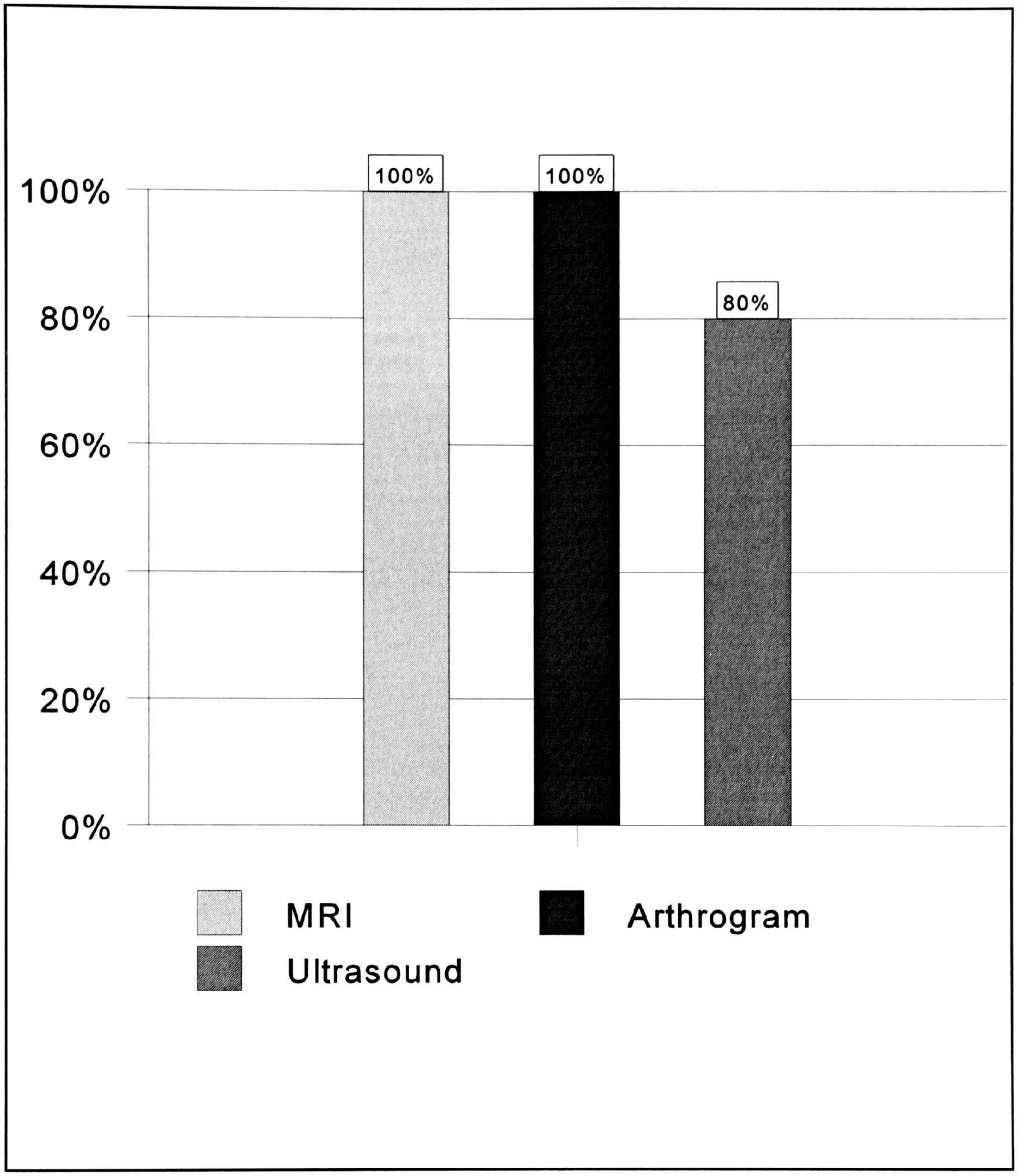

FIGURE 1 POSITIVE PREDICTIVE VALUE FOR THE CURRENT STUDY

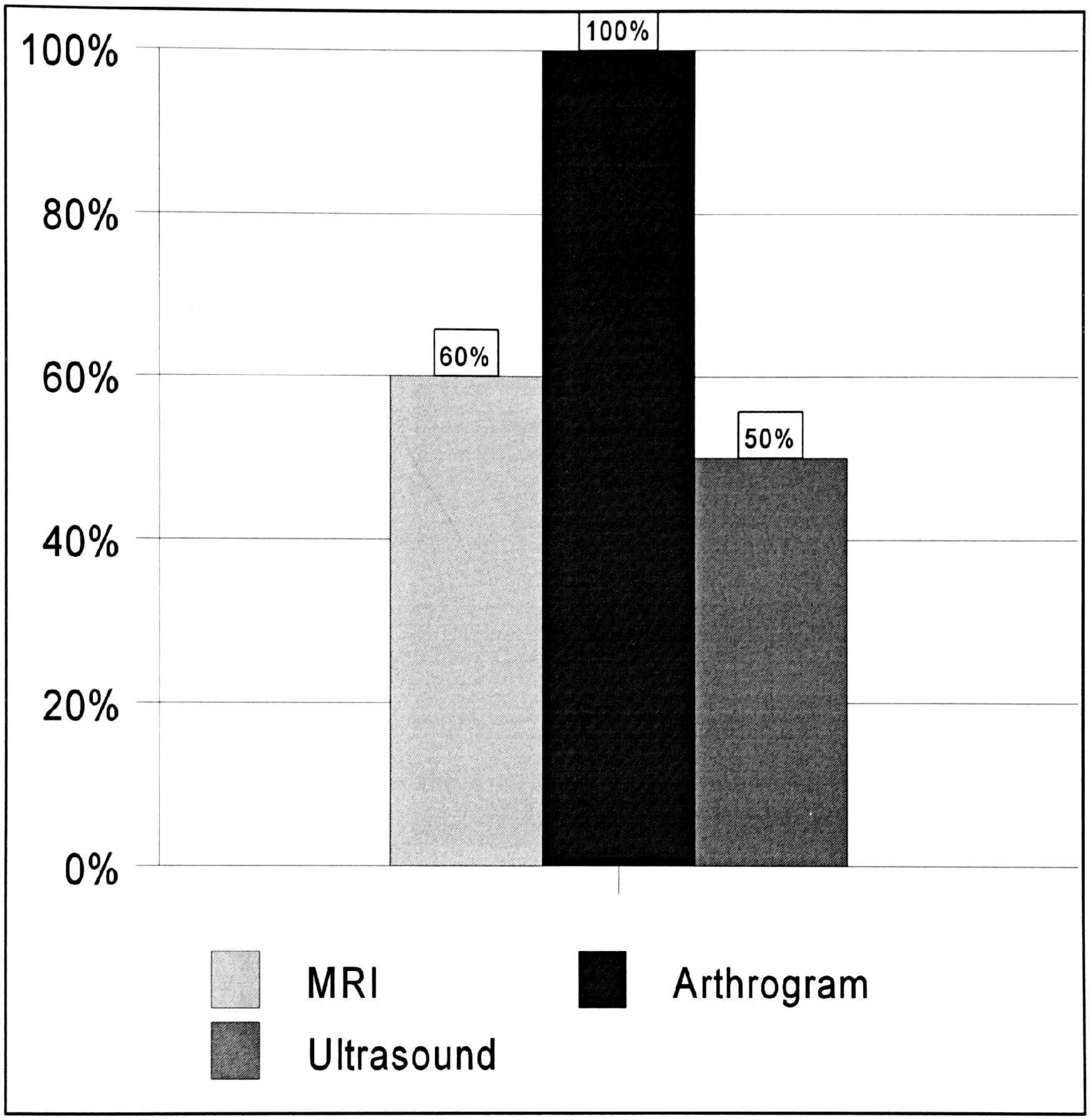

FIGURE 2 NEGATIVE PREDICITIVE VALUE FOR THE CURRENT STUDY

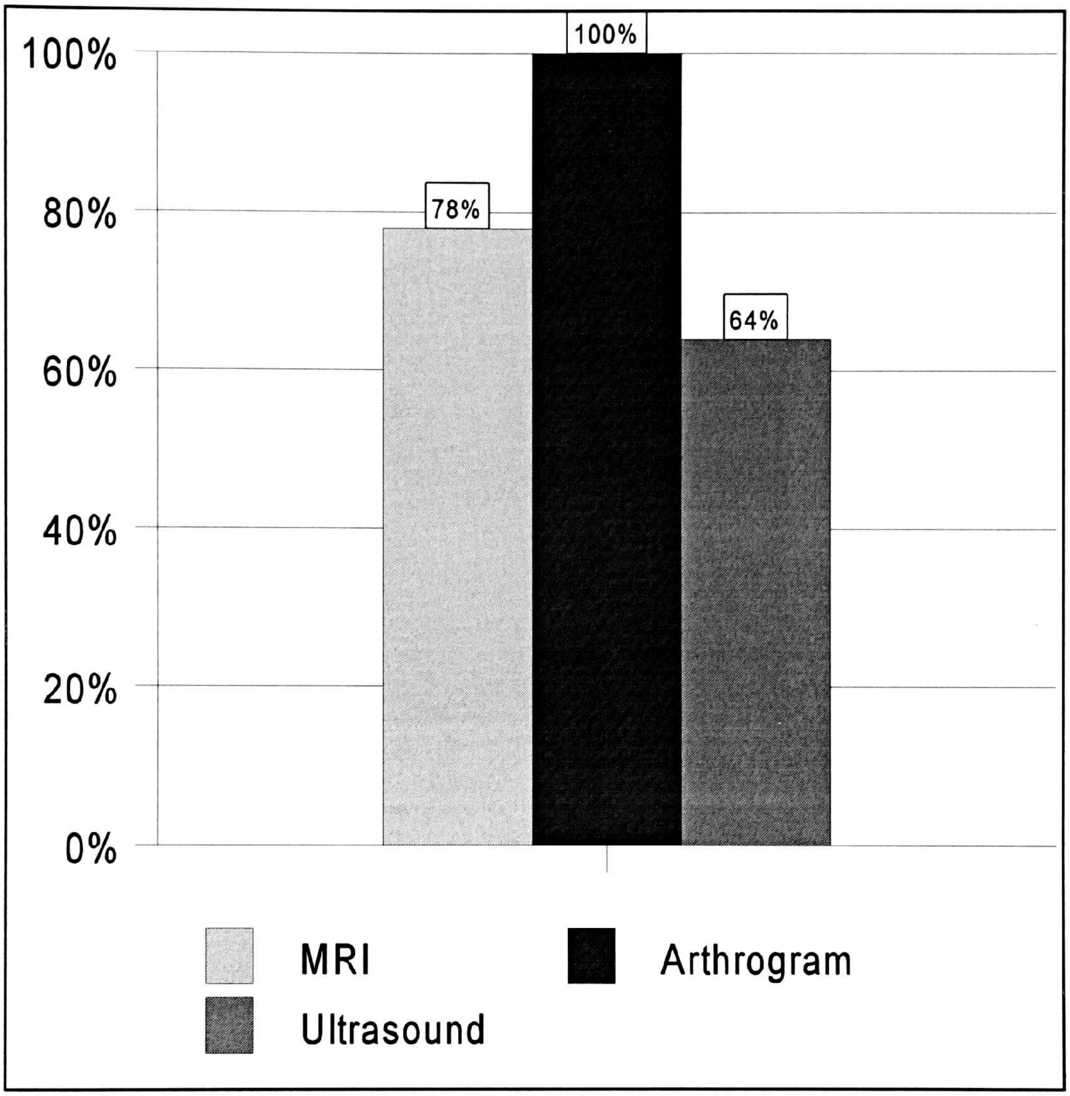

FIGURE 3 ACCURACY FOR THE CURRENT STUDY

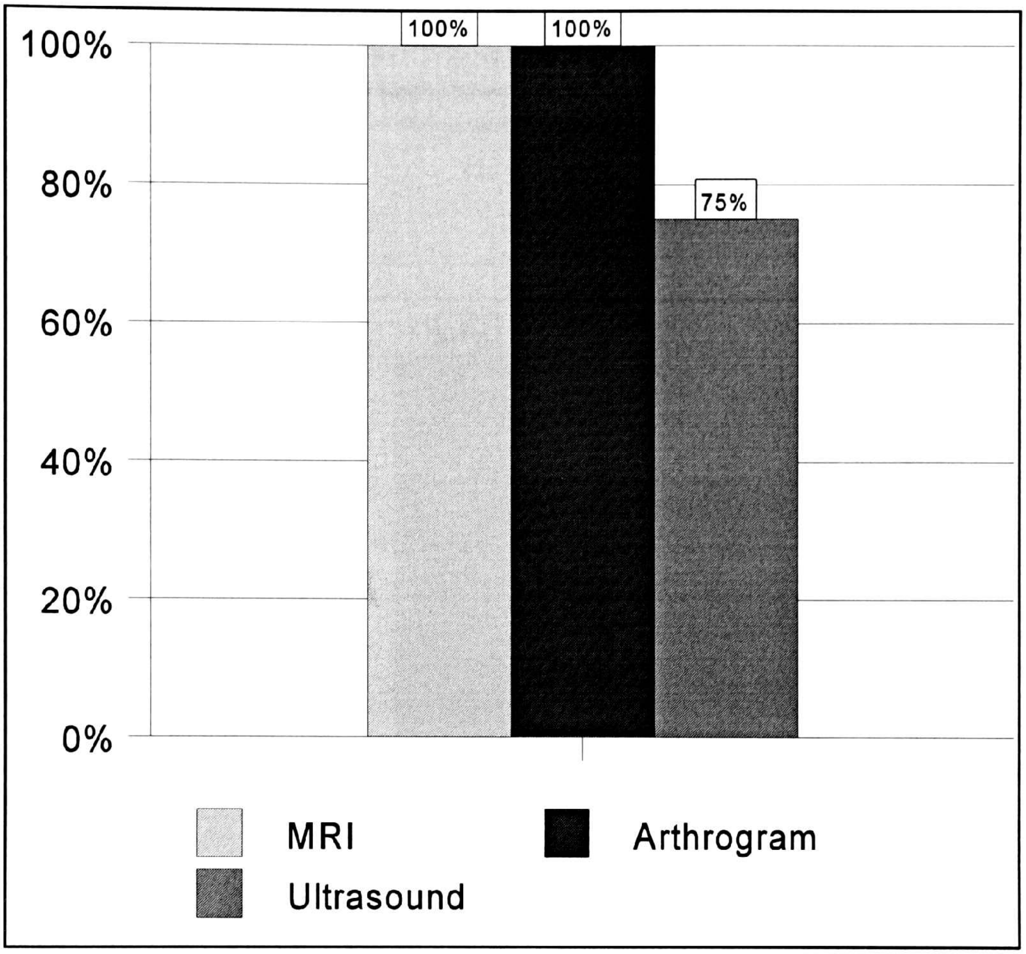

FIGURE 4 SPECIFICITY FOR THE CURRENT STUDY

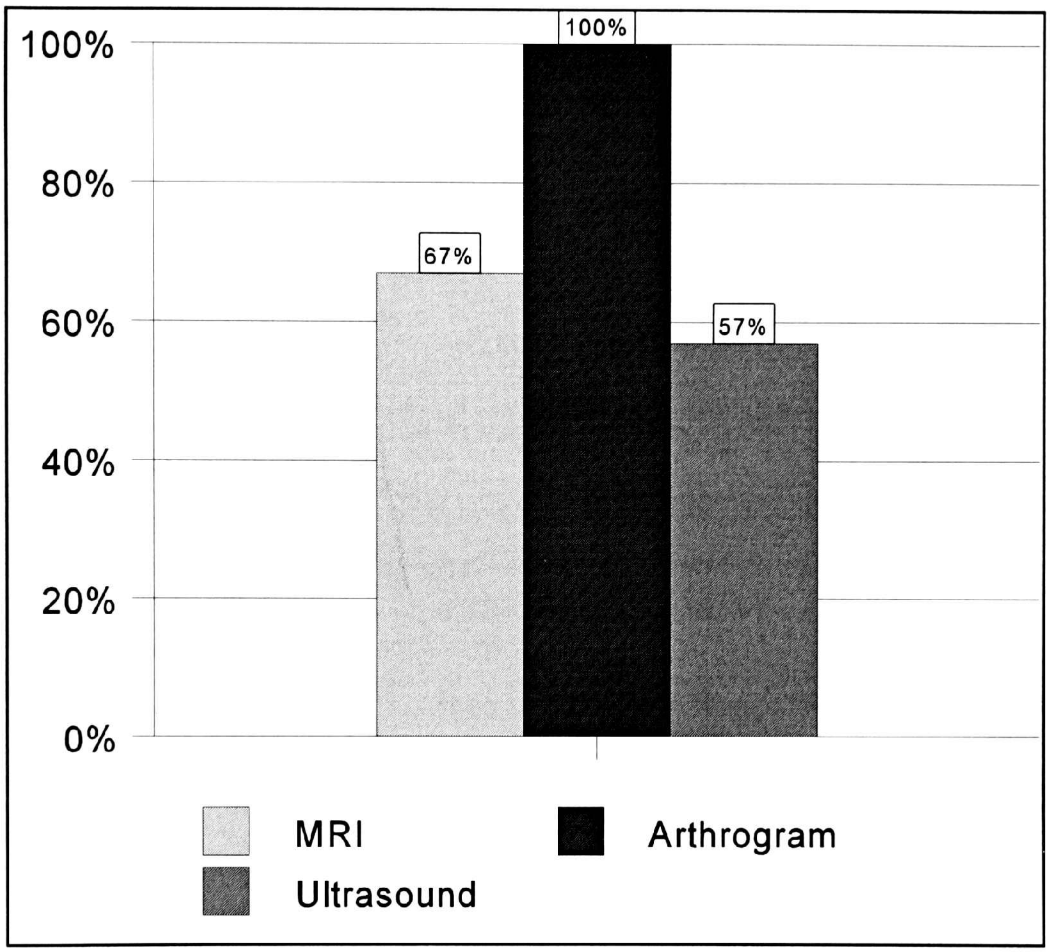

FIGURE 5 SENSITIVITY FOR THE CURRENT STUDY

APPENDIX A

Delimitations

All patients are from Southeast Georgia.

All results are reported to the physician prior to surgical evaluation. The surgeon may spend an unusual effort trying to find a rotator cuff tear found on a non-prescribed study.

Limitations

There is no randomization of subjects.

The number of subjects is dependent on the number of patients referred.

The only files reviewed are those of volunteers and may not represent the entire population.

Assumptions

If no surgery is performed after four weeks after a report of a negative diagnostic test, and there is patient improvement, there is no rotator cuff tear.

The surgeon and/or the radiologist will not make an unusual effort to locate a rotator cuff tear based on the results of the non-prescribed studies.

Signficance of the Study

The significance of this study is to provide information to health care professionals on the agreement of MRI, arthrogram, ultrasound, and surgery so that they may better prescribe correct, quick, safe, economical, diagnostic studies with which to evaluate possible tears of the rotator cuff.

APPENDIX B

Definitions

sensitivity- the probability that the clinical test declares those persons positive who have the disease; number of true positives ÷ (number of true positives + number of false negatives)

specificity- the probability that the clinical test declares those persons negative who are without the disease; number of true negatives ÷ (number of true negatives + number of false positives)

accuracy-total number of correct diagnosis ÷ total number of shoulders

positive predictive value- number of true positives ÷ (number of true positives + number of false positives)

negative predictive value- number of true negatives ÷ (number of true negatives + number of false negatives)

false positive - classifying a person as diseased when one is not

false negative - classifying a person as not diseased when one has the disease

APPENDIX C

RAW DATA

PATIENT	MRI	ARTHROGRAM	ULTRASOUND	SURGERY
1		+	--	+
2*	--		+	--
3	--		+	+
4	+		--	+
5	+		+	+
6*		--	--	--
7*	--		--	--
8	+		+	+
9	+		--	+
10	--	+	+	+
11*	--		--	--

LEGEND:

(+) POSITIVE ROTATOR CUFF TEAR

(-) NEGATIVE ROTATOR CUFF TEAR

BLANK NO RESULTS AVAILABLE/NOT PERFORMED

(*) CLINICAL DIAGNOSIS OF NO ROTATOR CUFF TEAR. NO SURGERY PERFORMED