Predicting Conservative Treatment Outcomes in Patients with Degenerative Rotator Cuff Tears using Machine Learning

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INTRODUCTION:

Degenerative supraspinatus tears are among the most frequent causes of shoulder pain and dysfunction in adults, particularly in middle-aged and elderly populations. Despite a wide spectrum of presentations, most non-traumatic full-thickness degenerative tears can be managed conservatively yielding satisfactory results in up to 75% of patients. However, evidence suggests that patients who fail conservative treatment and undergo delayed surgery experience inferior outcomes compared to those treated surgically from the begining. Consequently, identifying early which patients are likely to fail non-operative management could help optimize care and improve functional outcomes. The use of artificial intelligence (AI) and machine learning (ML) to process large datasets allows for the detection of complex, non-linear interactions between variables that are difficult to see using traditional statistical methods. In this context, the aim of this study was to develop a model using machine learning techniques able to identify with good accuracy which patients with degenerative supraspinatus tears are going to fail conservative treatment. Our hypothesis is that is feasible to develop such prediction model.

METHODS:

From 2022 to 2024, we prospectively enrolled consecutive patients with degenerative supraspinatus tears who initially opted for conservative treatment. Exclusion criteria included patients older than 75 years, partial, massive or traumatic tears, advanced fatty degeneration (Goutallier >2), arthritic changes (Hamada >2), Subscapularis tear Lafosse type >2, history of instability or nerve injury and prior surgery on the affected shoulder. All patients underwent a standardized physiotherapy protocol and were followed at 3, 6, 12, and annually. The analysis was conducted at the 2-year follow-up. Surgery was offered if functional improvement was not achieved after at least 3 months. Collected variables included demographics, occupation, hand dominance, MRI tear characteristics (size in coronal and sagittal planes, ISAKOS classification, location within the tendon, involvement of other tendons), biceps pathology, fatty infiltration, arthropathy, history of corticosteroid injections, and comorbidities such as smoking, diabetes, hypertension, dyslipidemia, and hypothyroidism. Functional outcomes were assessed using the Visual Analogue Scale (VAS), Subjective Shoulder Value (SSV), and American Shoulder and Elbow Surgeons (ASES) score. The primary outcome was defined as the need for surgical intervention. The dataset was randomly divided into training (80%) and test (20%) sets using stratified sampling. Multiple data balancing techniques were evaluated, and feature selection was performed using an evolutionary algorithm. The final predictive model employed a Balanced Random Forest Classifier to address class imbalance. Model performance was assessed using standard classification metrics, the area under the curve (AUC) and interpretability was provided through SHAP (SHapley Additive Explanations) values.

RESULTS:

Among the 347 patients, mean age was 63.5 years, 66% were female, 49% manual workers, and 67% had tears on the dominant side. Mean tear size was 16.3 mm (coronal) and 13.8 mm (sagittal). According to ISAKOS classification, 49% were C1, 37.6% C2, and 13.2% C3. The anterior third was the most frequent location (70%), with infraspinatus involvement in 46.7% and subscapularis (Lafosse I) in 57.9%. Goutallier II fatty infiltration was seen in 19.5%. LHBT findings included normal (30.3%), partial tear (18.7%), subluxation (37.5%), dislocation (5.5%), and absence (7.8%). Prior corticosteroid injection was reported in 26.8%. Comorbidities included smoking (21.3%), diabetes (10.9%), dyslipidemia (34.9%), hypertension (33.1%), and hypothyroidism (12.1%). Mean scores were VAS 7.3, SSV 37.3, and ASES 46.4. Night pain was reported by 75.8% of the patients.

At the end of the follow-up, 66 patients (19%) required surgery after failing conservative treatment. In the descriptive analysis, statistically significant differences were observed between surgical and non-surgical groups in age (58.5 vs. 64.6 years, p=0.001), BMI (28.8 vs. 27.2, p=0.016), subscapularis involvement (13.5% vs. 3%, p=0.042), VAS (7.7 vs. 7.2, p=0.018), SSV (30.9 vs. 38.9, p=0.003), and ASES score (40.6 vs. 47.1, p=0.001).

The final model achieved high predictive performance with a sensitivity of 94%, specificity of 62%, overall accuracy of 83%, positive predictive value of 89%, negative predictive value of 77%, F1-score of 91.7%, and area under the curve (AUC) of 0.84 (95% CI: 0.689–0.963). SHAP analysis showed that age, tear size (in both planes), and baseline functional scores were the most influential variables. Other variables selected by the model despite limited univariate significance included diabetes, smoking, corticosteroid injections, and Hamada classification, reflecting the importance of variable interactions in ML-based prediction.

DISCUSSION AND CONCLUSION:

This study demonstrates the feasibility and potential of using a machine learning algorithm to predict conservative treatment outcomes in patients with degenerative supraspinatus tears. Using the information available in the first patient´s

appointment (patient characteristics, MR images and functional scores) the model was able to predict if the patient will need surgery in the next two years. Such tools may support clinicians in early identification of patients unlikely to benefit from conservative care, guiding timely surgical referral and contributing to personalized treatment strategies.