Use of Multivariate Linear Regression Models and Support Vector Regression Models to Predict Outcome in Patients Undergoing Surgery for Cervical Spondylotic Myelopathy

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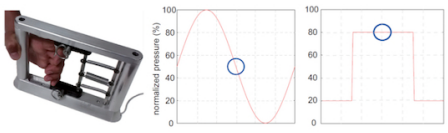
Introduction

Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord dysfunction and is characterized by spondylosis leading to compression of the spinal cord. The results of surgical management for CSM are variable, with Ebersold *et al* reporting long-term functional decline or no improvement in 45% of patients undergoing anterior cervical discectomy with fusion. Predicting outcomes after surgery for CSM remains a challenge. This study introduces the use of multivariate linear regression (MLR) and support vector regression (SVR) models to predict postoperative outcomes in a cohort of patients who underwent surgery for CSM. An accurate predictive model of functional outcome would optimize patient selection for surgery.

Methods

Patients were recruited who had a diagnosis of CSM and underwent decompressive surgery by one spinal surgeon. Fine motor function was tested during the preoperative consultation and at a minimum of three months postoperatively with a handgrip-based tracking device that has been previously validated (Lee *et al*), yielding mean absolute accuracy (MAA) results for two tracking tasks (sine and step). All patients completed Oswestry Disability Index (ODI) and modified Japanese Orthopaedic Association (mJOA) questionnaires at the time of handgrip testing. Age, duration of symptoms, narrowest spinal cord diameter, and preoperative MAA scores were utilized in MLR and SVR models to predict postoperative ODI.

Figure 1

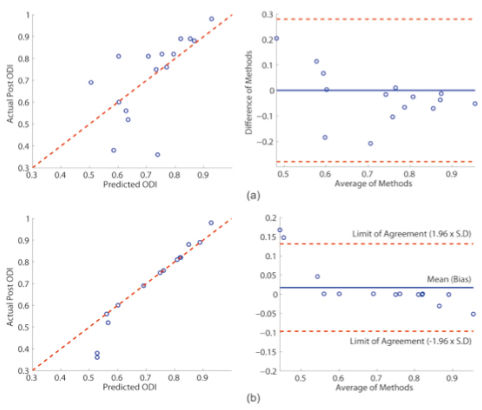


Left: The handgrip device used to detect grip strength in real-time. Middle: Sinusoidal tracking task. Right: Step tracking task.

Results

A total of 27 patients with CSM met the inclusion criteria and were followed as part of a 24-month cohort trial. 11 patients did not complete follow-up, leaving 16 patients (11 males, 5 females) with a mean age 62.3. The average clinical follow-up time was 7.9 months. With the MLR model, a combination of the preoperative ODI score, preoperative MAA (sine task), and preoperative MAA (step task) yielded the best prediction of postoperative ODI ($R^2 = 0.749$, MAD = 0.073, $p < .001$). With the SVR model, a combination of preoperative ODI score, preoperative MAA (sine task), and symptom duration yielded the best prediction of postoperative ODI ($R^2 = 0.954$, MAD = 0.028, $p < .001$). SVR produced superior regression performance ($p < 9.93 \times 10^{-11}$) compared to MLR ($p < 1.49 \times 10^{-5}$), as seen in Figure 2.

Figure 2



The regression plot (left) and its Bland-Altman plot (right) for (a) MLR and (b) SVR models.

Results (cont.)

In order to estimate the prognostic ability of each patient's preoperative fine motor function for predicting the postoperative functional outcome, MAA of the sine and step tracking tasks were removed from the analysis. Following this, the predictors that produced the best regression results were preoperative ODI, age, and symptom duration for the MLR model, and preoperative ODI, age, and preoperative mJOA for the SVR model. Although the regression results remained statistically significant, their performances were less robust. MAD values decreased approximately 30% for both MLR and SVR models, as shown in Table 1.

Table 1

	R^2	Adjusted R^2	p-value	MAD	Predictors
MLR	0.407	0.365	7.85×10^{-3}	0.0973	pre-ODI, age, months after injury
SVR	0.852	0.841	3.57×10^{-7}	0.0463	pre-ODI, age, pre-mJOA

Multivariate regression models when the handgrip fine motor function scores were removed from the analysis.

Conclusions

Using a combination of preoperative ODI score and performance on a task assessing fine motor function, postoperative ODI scores calculated by MLR and SVR models correlated well with the actual postoperative ODI score in patients who underwent surgery for CSM. The predicted ODI from the SVR model had a stronger correlation to the actual ODI and a smaller MAD than the predictions obtained from the MLR model. The greater performance of a more flexible predictive model suggests that even with the availability of prognostic factors, patients may not respond to surgery as expected if a linear relationship is assumed. The use of our SVR model would optimize patient selection for surgery to treat CSM.

References

1. Ebersold MJ, *et al.* Surgical treatment for cervical spondylitic myelopathy. *J Neurosurg*. 1995;82:745-51.

2. Lee SI, *et al*. A pervasive assessment of motor function: a lightweight grip strength tracking system. *IEE J Biomed Health Inform.* 2013;17:1023-30.