Performance Analysis of a Deep Learning Algorithm to Detect Positive SIJ MRI According to the ASAS Definition in axSpA Patients

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Objective

To assess the ability of a previously trained deep learning algorithm to identify the presence of sacroiliac joint inflammation in MRI scans in a study cohort of patients with axial spondyloarthritis.

Background

- MRI of the sacroiliac joints (SIJ) is an essential tool in the clinical diagnosis of patients with axial spondyloarthritis (axSpA), but in-depth knowledge of characteristic MRI lesions, their definitions, and reliability of identification and scoring vary among general radiologists and rheumatologists.[1]
- A trained deep learning algorithm to detect the presence of inflammation in SIJ MRI scans has previously been developed with promising results in a small patient cohort.[2]
- Further evaluation of the deep learning algorithm in larger external validation cohorts, specifically in non-radiographic (nr-) and radiographic (r-) axSpA populations, is required to assess its potential for (pre-) clinical use.

Methods

MRI Scans

- Baseline SIJ MRI scans were collected from patients with nr-axSpA or r-axSpA in two prospective randomised controlled trial cohorts (RAPID-axSpA [NCT01087762] and C-OPTIMISE [NCT02505542]).[3,4]
- The MRI scans were centrally evaluated by two human expert readers, and an adjudicator in case of disagreement, for the presence of SIJ inflammation as defined by the 2009 Assessment in SpondyloArthritis international Society (ASAS) definition of MRI positivity (MRI+).[5]
- The scans were then processed by the previously trained deep learning algorithm,[2] blinded to clinical information and central expert readings.

Model Performance Evaluation

- The agreement between the deep learning algorithm and expert readers for the binary classification of MRI SIJ scans (MRI+ vs MRI−) was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), absolute agreement and Cohen's Kappa.
- Bootstrapping was used to construct 95% confidence intervals (CIs).

Results

Baseline MRI Scans and Patient Characteristics

- In total, 731 MRI SIJ scans were collected from pooled patients in RAPID-axSpA (n=152) and C-OPTIMISE (n=579), comprising the validation set (**Figure 1**).
- In the pooled study population, 44.6% (n=326) were patients with nr-axSpA and 59.6% (n=436) were MRI+ as determined by expert readings (**Table 1**, **Figure 2A**).

Model Validation

- Comparing the trained algorithm with the central expert readings for the classification of MRI+/MRI− scans on the pooled validation set yielded a sensitivity of 0.70 (95% CI: 0.66–0.73), specificity of 0.81 (95% CI: 0.78–0.84), PPV of 0.84 (95% CI: 0.82–0.87), NPV of 0.64 (95% CI: 0.61–0.68) and absolute agreement of 0.74 (95% CI: 0.72–0.77; **Figure 2B–F**).
- The Cohen's Kappa of 0.49 (95% CI: 0.43–0.55; N=731; **Figure 2G**) reported here can be readily recalculated to a Matthews Correlation Coefficient (MCC) of 0.50; the MCC reported in the previous, smaller validation set was 0.62 (N=47).[2,6]

Summary

We tested the ability of a deep learning algorithm to identify MRI+ patients with axSpA

Proportion of patients classified as MRI+ by central expert readings:

Performance of the deep learning algorithm against expert readings[a]:

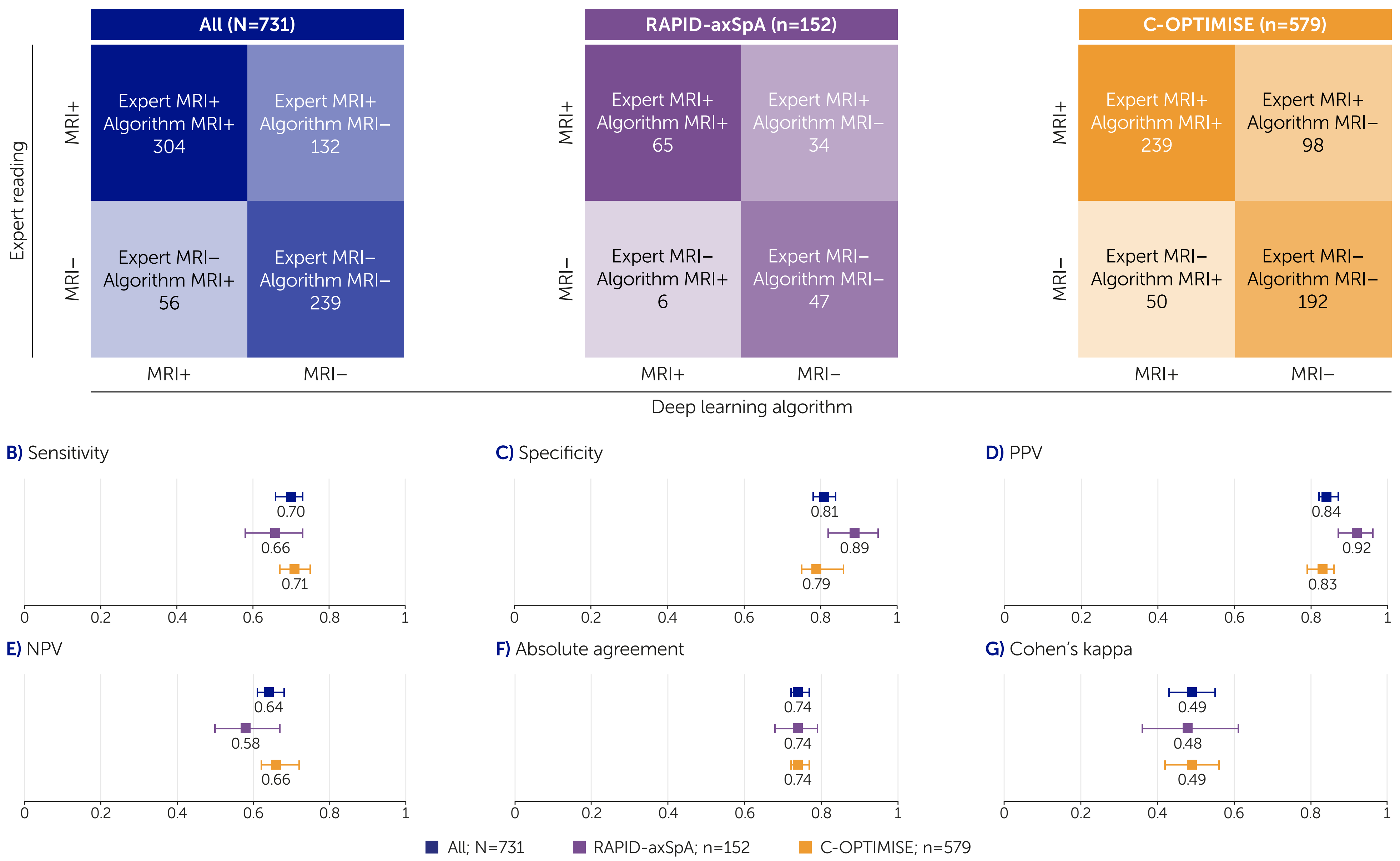
[a]Data for the pooled validation set (N=731).

Table 1 Patient demographics and baseline characteristics

Baseline characteristic, mean (SD), unless otherwise stated	All patients N=731	MRI+ by expert reading n=436	MRI− by expert reading n=295
Age, years, mean (SD)	34.2 (8.6)	33.4 (8.5)	35.3 (8.8)
Male, n (%)	505 (69.1)	304 (69.7)	201 (68.1)
BMI, kg/m², mean (SD)	25.8 (4.9)[a]	25.8 (5.0)[b]	25.8 (4.8)
HLA-B27 positive, n (%)	608 (83.2)	359 (82.3)	249 (84.4)
nr-axSpA, n (%)	326 (44.6)	216 (49.5)	110 (37.3)
Symptom duration, years, mean (SD)	4.8 (5.6)	4.7 (5.7)	5.0 (5.5)
Time since first diagnosis of axSpA, years, mean (SD)	3.1 (4.1)	2.9 (3.6)	3.5 (4.6)
ASDAS, mean (SD)	3.7 (0.8)[c]	3.8 (0.8)[b]	3.7 (0.8)[d]
BASDAI, mean (SD)	6.7 (1.4)[e]	6.6 (1.5)	6.7 (1.4)[f]
CRP, mg/L, median (min, max)	9.0 (0.1, 179.9)	9.0 (1.0, 179.9)	8.6 (0.1, 132.9)
BASFI, mean (SD)	5.3 (2.1)[a]	5.2 (2.1)[g]	5.4 (2.0)[f]

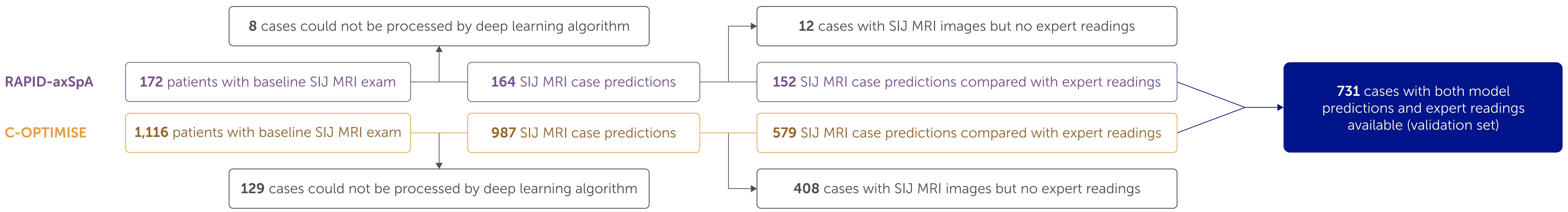
[a]n=729; [b]n=434; [c]n=727; [d]n=293; [e]n=730; [f]n=294; [g]n=435.

Figure 2 Performance results comparing the deep learning algorithm and human experts for classification of SIJ MRI scans



Metric values are point estimates; error bars show 95% CIs computed using bootstrapping (1000 iterations).

Figure 1 Study flow diagram



Conclusions

The previously trained deep learning algorithm enabled the acceptable detection of the presence of SIJ inflammation, according to the 2009 ASAS MRI definition, in a larger external validation set of patients with axSpA from two clinical trials.

This suggests that a detection algorithm for SIJ MRI+ has the potential to support clinicians in the diagnosis of patients with axSpA.

ASAS: Assessment of SpondyloArthritis international Society; **ASDAS:** Ankylosing Spondylitis Disease Activity Score; **axSpA:** axial spondyloarthritis; **BASDAI:** Bath Ankylosing Spondylitis Disease Activity Index; **BASFI:** Bath Ankylosing Spondylitis Functional Index; **BMI:** body mass index; **CI:** confidence interval; **CRP:** C-reactive protein; **HLA-B27:** human leukocyte antigen B27; **MCC:** Matthews Correlation Coefficient; **mNY:** modified New York; **MRI:** magnetic resonance imaging; **NPV:** negative predictive value; **nr-axSpA:** non-radiographic axSpA; **PPV:** positive predictive value; **r-axSpA:** radiographic axSpA; **SD:** standard deviation; **SIJ:** sacroiliac joints.

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