Summary Report: Rapid implementation of MR AAT in NHS North West England by The Christie MR physics group

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Executive Summary

Forty-seven MR scanners in North West England benefitted from MR Advanced Acceleration Technology (AAT) software funded by NHS England and NHS Improvement (NHSEI) North West (NW). Thirty of those scanners were in departments with MR clinical scientist support provided by The Christie Medical Physics and Engineering (CMPE) MR physics group. CMPE MR physics group followed the AAT implementation approach they developed alongside NHSEI NW. It was conclusively demonstrated that artificial intelligence (AI)-based AAT was a gamechanger technology and continued investment in this technology should be prioritised.

Across **eighteen** scanners with **AI-based AAT** licences funded by NHSEI NW, at trusts where CMPE MR physics group carried out the NHSEI NW implementation approach

- **16,040** estimated additional thirty-minute examination slots per year were generated
- **£1.87 million per year** estimated minimum cost avoidance from outsourced MR scanning

Across **fifteen** of those systems with reliable pre-AAT patient throughput data there was an

- **18.8 % patient throughput increase**

The above figures are derived from robust estimations across the region. Available processed patient throughput data has confirmed the estimation is fit for purpose. The percentage improvement in throughput for an individual scanner will vary from trust to trust depending on case mix and technology available. Individual cost avoidance to date at each trust will differ depending on the date(s) of appointment slot length reductions.

This summary report does not include data on the progress of AAT implementation for scanners in trusts in the North West not supported by CMPE MR physics group.

1. Introduction

In December 2021, NHS England and NHS Improvement (NHSEI) began a procurement process for MR Advanced Acceleration Technology (AAT) in two regions of England. This led to the first widescale rollout of these new technologies across the NHS. The aim was to increase MR patient throughput by at least 10% on each system benefitting from the AAT investment. The North West (NW) of England received approximately £5.1m in two tranches to install MR AAT across forty-seven systems. Thirty of these systems were in trusts with a service level agreement for MR physics support from the MR physics group at The Christie NHS Foundation Trust. The trusts were spread across the three integrated care systems (ICS) in NW England.

The scope of this summary report is twenty-seven scanners at twelve trusts across the North West of England, where The Christie MR physics group were able to carry out the dedicated implementation work recommended by NHSEI North West. Details of the trusts, hospitals, scanners and AAT licences included in this summary report are shown in Appendix 1. It was not possible to include three scanners in the analysis, see section 4.1.5 for further details. There are several acronyms unique to AAT used throughout the report. These are collected in Appendix 2.

2. Method

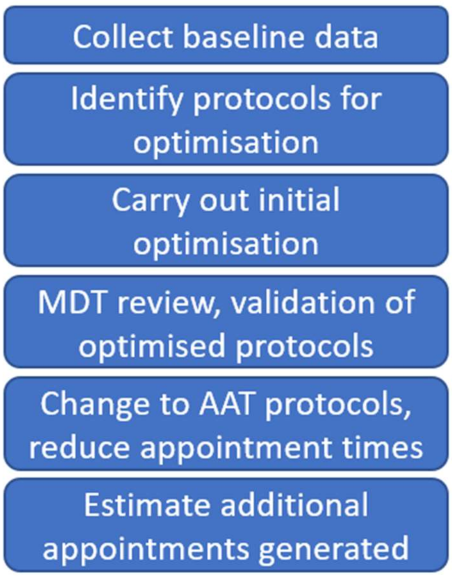

Figure 1. Method of rapid AAT deployment across NW England

2.1 AAT implementation at each trust

In collaboration with NHSEI North West, CMPE MR physics group devised an implementation plan to optimise commonly used clinical protocols as part of the wide deployment of AAT across the region, see Figure 1.

The baseline data collected comprised:

- Number of patients referred for each MR examination per month (average across previous year)
- A list of MR examination appointment slot lengths in use in each department
- The total acquisition time for each examination

This information was used to identify the priority protocols for optimisation by MR clinical scientists and senior MR radiographers. The key considerations were:

- The expected benefit of the available AAT on each clinical protocol
- The difference between the existing appointment slot and the sequence acquisition times
- The patient throughput for each examination; more common examinations were prioritised

The initial optimisation involved multiple healthy volunteer scanning sessions, lasting 3-8 hours, with 2 or more MR clinical scientists in attendance. Existing clinical protocols were acquired alongside protocols optimised using appropriate vendor-specific AAT. The goal of the optimisation was to accelerate each sequence, whilst maintaining or improving image quality. Details of the individual protocol optimisations made at each trust are beyond the scope of this summary report.

Qualitative review and comparison of AAT-optimised protocols against existing clinical protocols was carried out by consultant radiologist or reporting radiographer members of an AAT multi-disciplinary team (MDT) at each trust. Where an AAT sequence was found to be robust to artefact, quicker and with non-inferior image quality to the existing sequence it was introduced into the clinical protocol in place of the original sequence. In some cases, AAT-optimised sequences were run alongside the existing clinical protocol for a small number of patients for further review.

Following the introduction of optimised AAT sequences into clinical protocols, further reviews of patient imaging were carried out to ensure robustness to artefact and continued suitability of the AAT protocol. To increase patient throughput, MR examination appointment slot lengths were reduced at the discretion of each department where the AAT-optimised protocols permitted.

Month-to-month variability in workload on each scanner was expected. A robust estimate of impact of AAT on patient throughput for each optimised clinical protocol was calculated: the difference in appointment slot length in minutes before and after AAT implementation was multiplied by the estimated number of referrals per month from the pre-installation data, collected from the hospital radiology information system (RIS). This permitted an estimate of how many minutes of additional time would by generated by using the new appointment slot length in future at the same referral rate.

To estimate the impact of all AAT introduced for each scanner, the total additional minutes of scanner time and the total number of additional thirty-minute slots generated were calculated. This calculation allowed a consistent metric of AAT impact across the region. The justification for using this metric instead of raw patient throughput data from the RIS is discussed in section 4.2.5.

2.2 AAT evaluation across the CMPE-supported trusts in the region

The estimated number of additional thirty-minute appointment slots generated by CMPE-supported AAT optimisation across twenty-seven scanners in North West England was collated and stratified by scanner manufacturer and the type of AAT. Where possible, the annual number of MR examinations for each scanner pre-AAT was compared with the estimated additional 30-minute appointment slots per year, and a percentage increase was calculated. The estimated cost avoidance due to reduced outsourcing to the private sector was calculated based on the NHSEI provided average figure of £116.80 per MR scan.

3. Results

Key message: total impact

An estimated **16,040** additional 30-minute appointment slots per year were generated on eighteen CMPE-supported scanners with AI-based AAT licences in North West England.

Key message: percentage impact

There was an estimated average increase in patient throughput of **18.8%** for fifteen CMPE-supported scanners with AI-based AAT where robust pre-AAT data was available**.**

Key message: cost avoidance

Providing 16,040 additional MR appointments via outsourcing MR scans to the private sector would cost an estimated **£1.87 million per year,** based on cost estimates provided by NHSEI

Figure 2 shows the estimated number of additional thirty-minute appointment slots generated by CMPE-supported AAT optimisation across twenty-seven scanners in North West England, per scanner per month, stratified by scanner manufacturer and AAT licence type installed.

Figure 3 shows the estimated number of additional thirty-minute appointment slots generated by CMPE-supported AAT optimised protocols per year alongside the estimated number of appointment slots pre-AAT licence installation, for fifteen of the eighteen scanners in the project who received AAT licences with AI technology. Three scanners at Blackpool did not have robust enough pre-AAT data to be included in this figure.

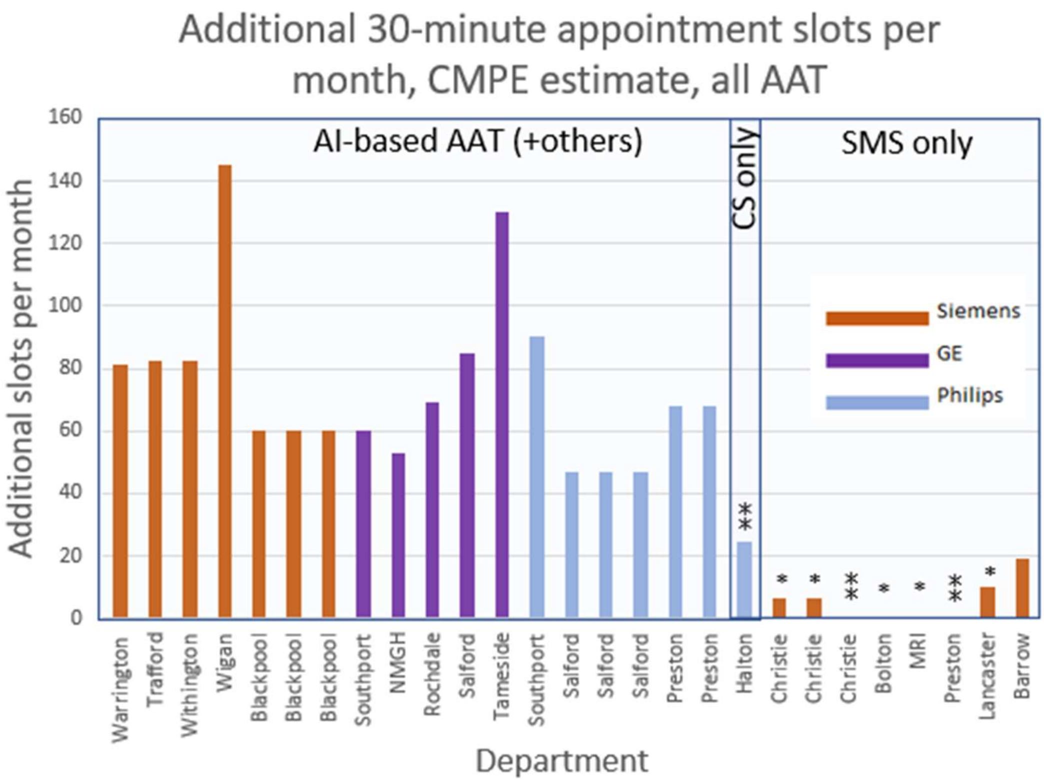

Figure 2. Estimated number of additional thirty-minute examination slots created on MR scanners optimised by Christie MR physics, stratified by scanner manufacturer and AAT. See glossary for specific AAT definitions. *scanner case mix not favourable to SMS. ** 3 T scanner.

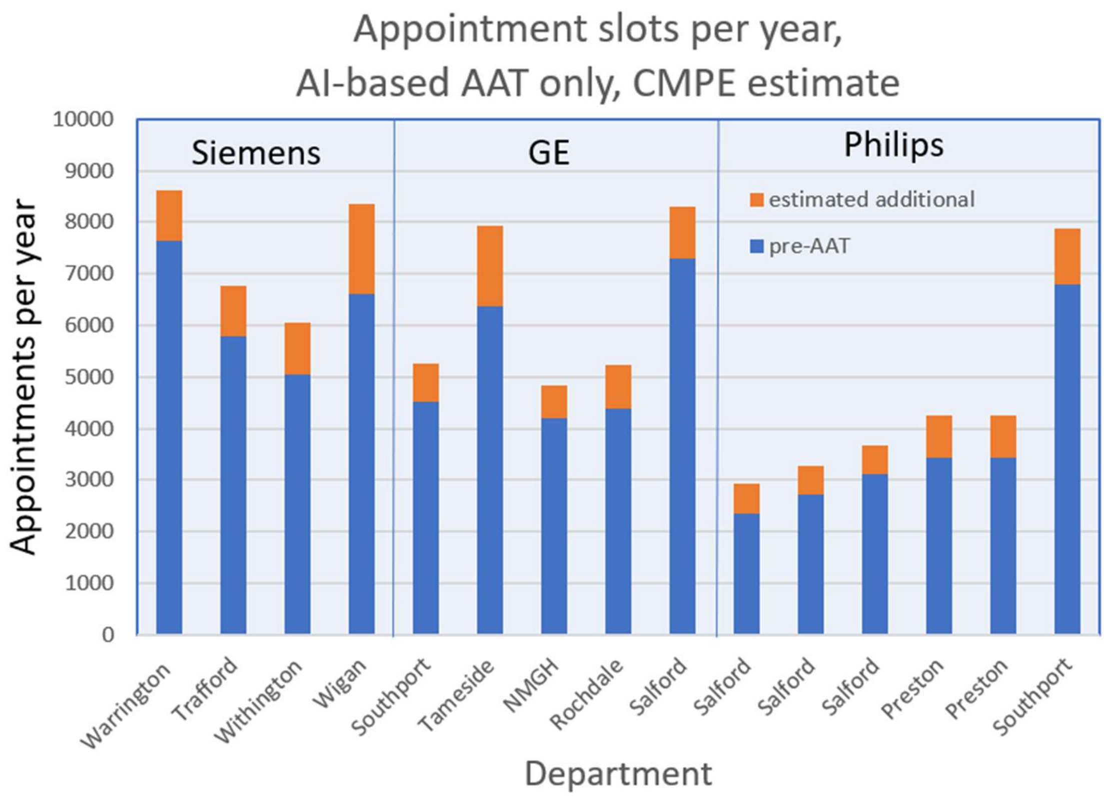

Figure 3. Estimated number of additional thirty-minute examination slots per year created by the project, alongside estimated pre-AAT throughput, for fifteen scanners with AI-based AAT licences. Three scanners at Blackpool did not have robust enough pre-AAT data to be included in this figure.

4. Discussion

4.1 Interpretation of the results

4.1.1 Stratification by AAT

Figure 2 clearly demonstrated successful implementation of AI-based AAT across all 3 manufacturers for AAT-compatible scanners in the region.

Key message: AI-based AAT is a gamechanger technology, capable of delivering increased throughput for MR departments.

Key message: Future investment in MR AAT should prioritise AI-based solutions and keep abreast of the latest technology available from manufacturers.

Key message: AI-based AAT should be included in the software requirements when procuring new MR scanners.

The individual differences between services and manufacturers in figure 2 can be attributed to many factors, including but not limited to: differences in manufacturer technology, case mix on each system and the existing efficiencies in scheduling. Figure 2 shows less successful implementation of SMS-based AAT, this is discussed in section 4.1.6.

4.1.2 Evaluation of the project against the stated target of a 10% increase in throughput

Key message: The estimated 18.8% average increase in patient throughput from AI-based AAT across fifteen scanners with reliable pre-AAT data exceeded the stated target of 10%.

One department that received only CS-based AAT showed an estimated 4.8% increase in patient throughput.

4.1.3 Evaluation of the project versus the cost of outsourcing MR scans to the private sector

Of the £5.1m invested in the project across the North West, the amount spent on AI-based AAT licences and any associated hardware upgrades required at trusts supported by CMPE MR physics was £2.74 million across the eighteen scanner in this analysis. The cost of the software licences alone was £1.67 million. The hardware upgrades comprised a full system refresh of two end-of-life scanners, which will provide many additional years of scanning.

Key message: AI-based AAT has proven to be a good return on investment, with costs recouped in under 18 months, for scanners supported by CMPE MR physics group.

The benefit of the licences will continue for the expected lifetime of the scanners and will benefit future MR scanners in each trust (see section 4.4.2).

4.1.4 Evaluation of the project versus the cost of installing further MR scanner capacity

To achieve the calculated increased throughput across the CMPE-supported sites in the North West via additional scanner capacity would require three additional scanners with AI-based AAT. An estimate of the cost required to purchase, site and staff additional scanners is complex but would need to consider the following:

- Capital costs of multiple additional scanners, including construction of new departments
- Staffing costs for multiple additional scanners
- Manufacturer service contracts across the expected lifetime of each scanner

A conservative estimate of capital costs alone for three MR scanners is £2.4 million. This exceeds the cost of the software licences for the CMPE supported systems with AI-based AAT in this project.

4.1.5 Data that was not included

Data for one scanner at The Christie NHS Foundation Trust was not included for consistency of analysis. First generation AI-based AAT (DRG) was implemented on this scanner outside of this project. Additional AI-based AAT (DRB) was funded by NHSEI NW. Scans are significantly accelerated, but the site has taken the decision not to reduce appointment slots on this system at present, to allow for greater inpatient flexibility. Optimisation work was not carried out on two other scanners at Trusts with CMPE support because the scanners are not currently staffed by NHS radiographers, see appendix 1.

Figure 3 shows the estimated impact of the AI-based AAT across one year for fifteen of the eighteen scanners supported by CMPE with AI-based AAT. Data for the three scanners at Blackpool was not included due to non-representative pre-AAT data. This was because rolling scanner replacements led to significant outsourcing for a long period before the AAT implementation. In addition, there were significant changes in specification between the old and new scanners within the trust, and an additional scanner was added to the service during this time.

4.1.6 Simulataneous multi slice (SMS) based advanced acceleration technology (AAT)

Figure 3 shows that, for certain models of Siemens scanner where AI-based AAT was not available, SMS-based AAT led to a modest or no increase in patient throughput. Reasons for this include

- SMS has been shown to be most effective for musculoskeletal (MSK) scanning with dedicated receive coils that surround the anatomy.
- Four of the six sites who received SMS as their primary AAT do not routinely scan MSK patients as part of their clinical protocol mix, for different reasons. One of the four is a tertiary cancer centre, where referrals for disease requiring specific MSK coils are uncommon (The Christie NHS Foundation Trust). The remaining three are acute sites whose main workload comprises inpatients for non-MSK referrals (Manchester Royal Infirmary, Royal Bolton Hospital and Royal Lancaster Infirmary). Routine MSK scans at each of these departments are scanned elsewhere within the trust, for example on a mobile MR scanner or a Community Diagnostic Centre (CDC).
- At Royal Bolton Hospital, one of the sites with an acute case mix, despite 8 days of optimisation work out of hours, and the adoption of some SMS (and CS) optimised sequences in the clinical protocol tree it was not possible to reduce any appointment slot times, as these were already among the lowest in the region.
- Implementation of SMS on the 3 T scanners at The Christie NHS Foundation Trust and Royal Preston Hospital was inhibited by MR safety restrictions related to the increased RF exposure required for this technology at this field strength.

Key message: SMS-based AAT alone did not bring an appreciable patient throughput increase to acute sites whose case mix did not include routine MSK work.

The time pressure to purchase the software in addition to the limited data available about the flexibility of SMS-based AAT at the time of purchase meant that decisions were taken that, in hindsight, did not represent value for money.

Where SMS optimised protocols were deployed but the appointment slot times were not reduced (at Bolton and The Christie NHS Foundation Trust) individual patients still benefit from shorter sequences.

4.2 The use of estimated additional 30-minute slots generated across the region

4.2.1 Justification for the estimation

A direct comparison of patient scan slot lengths before and after the implementation of AAT, which are recorded on hospital RIS systems, was confounded by multiple factors:

- Extended scanner downtime for upgrades and breakdowns.
- Difficulty isolating the throughput on scanner(s) with AAT in multi-scanner departments where some scanners do not have AAT.
- Redistribution of workload between scanners in multi-scanner departments, where some scanners do not have AAT.
- Changes to outsourced activity that impacts the mix and complexity of scans performed on scanners within the trust.
- Changes in services, for example commencing an MR Conditional CIED service which requires longer appointment slot lengths.
- Removal of the additional cleaning time added to appointment slots during the initial phase of the Covid pandemic.

Key message: Direct measurement of throughput increases via RIS/DM01 data is confounded in many interlinked ways and is not recommended.

Despite this finding, it is possible to generate useful data from RIS outputs with significant post-processing, if the service has been stable enough to permit this, see table 1 below.

4.2.2 Accuracy of the additional thirty-minute appointment slot estimation

The accuracy of the estimated additional 30-minute appointment slots shown in figure 2 is expected to be dependent on the nature of each service. For complex services in an acute hospital it is expected to be robust, whilst for outpatient only scanners in a community diagnostic centre (CDC) it is expected to be conservative. This is because many routine AAT-enabled protocols best suited to outpatient appointments at CDC's have appointment slot lengths that are less than the thirty-minute duration chosen for the regional analysis (e.g. knee, ankle, lumbar spine).

Processed data from two representative scanners with stable services post-AAT implementation at Manchester University Foundation Trust across 5 months are shown in table 1.

MR department	Service	CMPE-estimated additional 30-minute appointment slots/month via AI-based AAT	Processed RIS data: additional patients per month
North Manchester General Hospital	Acute hospital, single scanner department	53	59
Withington Community Hospital	Outpatient only Community Diagnostic Centre	82.5	126

Table 1: Comparison between the CMPE-estimated additional 30-minute appointment slots per month generated by AAT and the measured number of additional appointment slots, averaged over 5 months, on two scanners with sufficient service consistency to permit the calculation.

Table 1 shows that the estimated number of additional appointment slot estimation is robust for acute services and likely an underestimate for routine outpatient scanners.

4.3 Evaluation of the rapid optimisation method

The acquisition of original and AAT protocols in clinical patient appointments for direct comparison was considered as an alternative to volunteer imaging but not pursued. This is because it would have taken prohibitively long to achieve the same results across so many scanners and services. In addition, hundreds of patients would have needed to undergo additional imaging as part of their appointments.

The MR scanner time dedicated to volunteer imaging across the region was recouped in under 3 months once appointment slot lengths were adjusted. The hours of CMPE MR physicist preparation and analysis for each session was not captured but is known to be significant. This was absorbed into existing SLAs at no extra cost to each Trust.

Key message: Protected scanner time for dedicated healthy volunteer imaging was essential to ensure rapid deployment of the technology across the region. Payback time in terms of MR scans lost to volunteer imaging was short for AI-based AAT.

4.4 Wider benefits of AAT

4.4.1 Patients

Reduced MR examination slot lengths have benefits beyond reducing waiting lists. Anecdotal evidence from patients and radiography staff have confirmed that:

- quicker protocols bring an improved patient experience.
- patients who reported feeling anxious about MR scans in the past have reported they will no longer worry for future appointments having experienced AAT-optimised protocols.
- reduced need for sedation and general anaesthetic for patients with severe claustrophobia.
- more completed exams for confused patients who are unable to keep still for a long period.
- simpler to adhere to MR safety conditions regarding maximum scan time for some active implanted medical devices such as neurostimulators.

Key message: MR examination time reduction via AAT software is beneficial for patients.

4.4.2 Using optimised protocols on other scanners across the region

The analyses above have been completed only for those scanners supported by CMPE MR physics group, whose AAT licences were funded through the NHSEI MR AAT initiatives and where examination slot lengths have been reduced. The benefit of the work done during this project to any subsequent installations or upgrades within the region is not captured by this analysis. AAT optimised MR protocols can immediately be transferred to new or upgraded scanners from the same manufacturer within the same trust if the relevant AAT licences are present. The corresponding reduced appointment slot lengths can be implemented immediately. This has already happened at Manchester University NHS Foundation Trust, Wigan, Wrightington and Leigh NHS Foundation Trust and Warrington and Halton Hospitals NHS Trust, and more are expected.

Transferring AAT optimised protocols between trusts in the region was not attempted due to differences in local MR protocols and differences between the AAT software implementation by each manufacturer.

Key message: The optimisation work is already benefitting additional scanners in the North West. The additional capacity generated is not captured by the analysis in this summary report.

5. Conclusion

CMPE MR Physics group followed the MR AAT rapid implementation guidance we developed alongside NHSEI North West for twenty-seven of the forty-seven scanners across the North West who had AAT licences funded by NHSEI. Of these, fifteen scanners with AI-based AAT achieved an average increase of inpatient throughput of at least 18.8%, much greater than the target increase in patient throughput of 10%. The estimated cost avoidance from outsourcing MR scans was £1.87 million per year across eighteen systems (those receiving the AI-based AAT). This compared favourably with the £2.74 million in hardware and software upgrades on these systems.

Rapid implementation of AAT was possible thanks to MR physics leadership and support from MR managers, radiologists and radiology managers to facilitate healthy volunteer scanning and image review at scale.

Of the 9 scanners supported by CMPE which received non-AI-based AAT, the increase in patient throughput was modest to null. This was dependent on, but not limited to, the flexibility of the non-AI-based AAT and scanner case mixes. Future investment in MR AAT should prioritise AI-based solutions and keep abreast of the latest technology available from manufacturers.

Appendix 1 – Details of the Trusts, hospitals, scanners and AAT licences included in this summary report.

Integrated Care Service	Trust	Hospital	Scanner(s) (software version after wave 2 of funding)	AAT purchased and installed
Greater Manchester	Bolton NHS Foundation Trust	Royal Bolton Infirmary	Siemens Sola (XA30)	SMS, CS
Greater Manchester	Manchester University Foundation Trust	Manchester Royal Infirmary	Siemens Aera (XA30)	SMS
Greater Manchester	Manchester University Foundation Trust	North Manchester General Hospital	GE Signa Explorer Lift (MR29.1)	ARDL and HyperSense
Greater Manchester	Manchester University Foundation Trust	Trafford General Hospital	Siemens Sola (XA51)	Deep Resolve Boost, Gain, Sharp, CS
Greater Manchester	Manchester University Foundation Trust	Withington Community Hospital	Siemens Sola (XA51)	Deep Resolve Boost, Gain, Sharp
Greater Manchester	Northern Care Alliance NHS Foundation Trust	Rochdale Infirmary	GE Signa Explorer Lift (MR29.1)	ARDL and Hypersense
Greater Manchester	Northern Care Alliance NHS Foundation Trust	Salford Royal Hospital	GE MR450 (MR29.1)	ARDL and HyperSense plus full system hardware refresh
Greater Manchester	Northern Care Alliance NHS Foundation Trust	Salford Royal Hospital	Philips Ambition X x3 (R11.1)	Smartspeed AI
Greater Manchester	Tameside and Glossop Integrated Care NHS Foundation Trust	Tameside Hospital	GE Optima MR450W	ARDL and HyperSense
Greater Manchester	Wigan, Wrightington and Leigh NHS Foundation Trust	Royal Albert Edward Infirmary (Wigan)	Siemens Sola (XA51)	Deep Resolve Boost, Gain, Sharp
Greater Manchester		The Christie Hospital	Siemens Sola (XA51)	Deep Resolve Boost

	The Christie NHS Foundation Trust		Siemens Aera (XA30) x2, Skyra (XA30)	SMS
Lancashire and South Cumbria	Lancashire Teaching Hospitals NHS Foundation Trust	Royal Preston Hospital	Siemens Skyra (XA30)	SMS
		Royal Preston Hospital	Philips Ingenia x 2 (R11.1)	SmartSpeed AI
	University Hospitals of Morecambe Bay NHS Foundation Trust	Royal Lancaster Infirmary	Siemens Aera (VE11)	SMS
		Furness General Hospital	Siemens Aera (VE11)	SMS
	Blackpool Teaching Hospitals NHS Foundation Trust	Blackpool Victoria Hospital	Siemens Sola (XA51) x2	Deep Resolve Boost, Gain, Sharp
		Whitegate Drive Health Centre	Siemens Sola (XA51)	Deep Resolve Boost, Gain, Sharp
Cheshire and Merseyside	(now) Mersey and West Lancashire Teaching Hospitals	Southport and Formby District General Hospital	GE Signa Explorer Lift (R29.1)	ARDL and HyperSense plus full system hardware refresh
		Southport and Formby District General Hospital	Philips Ingenia (R11.1)	SmartSpeed AI
	Warrington and Halton Hospitals NHS Trust	Warrington Hospital	Siemens Sola (XA51)	Deep Resolve Boost, Gain, Sharp
		Cheshire and Merseyside Treatment Centre	Philips Ingenia 3T (5.7.2)	Compressed SENSE

Table A1. Systems with SLAs with The Christie MR physics group that benefitted from AAT installations from NHSEI North West, where optimisation work was carried out according to guidance provided by NHSEI NW.

*Two scanners with MR physics contract with Christie MR physics group were not included in this analysis, Liverpool Women’s Hospital and Chorley and South Ribble Hospital. The Siemens Sola at Liverpool Women’s Hospital is not currently run by NHS radiography staff, and protocols for this scanner are provided by other hospitals in the Cheshire and Merseyside ICS not supported by Christie MR physics group. The Philips Ingenia at Chorley is not currently staffed by NHS staff.

Appendix 2 – Glossary of AAT related acronyms used in the report

AI – artificial intelligence (vendor neutral)

ARDL – Air™ Recon DL, GE AI technique (GE)

CS – compressed sensing, method of accelerating signal acquisition via incoherent undersampling and iterative de-noising. Vendor specific: Compressed Sensing (Siemens), Compressed SENSE (Philips), HyperSense (GE)

DR – Deep Resolve, Siemens AI umbrella term (Siemens)

DRG – Deep Resolve Gain, Siemens intelligent de-noising technique (Siemens)

DRS – Deep Resolve Sharp, Siemens AI based image resolution enhancement (Siemens)

DRB – Deep Resolve Boost, Siemens raw data to image deep learning technique, released after DRG, AI based de-noising, unlike DRG (Siemens)

HyperSense – see CS (GE)

SMS – simultaneous multi-slice, method of accelerating signal acquisition via acquiring image data from multiple slices at once. Vendor specific: Simultaneous Multi-Slice (Siemens), MultiBand SENSE (Philips), HyperBand (GE)