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Investigating the feasibility of using A.I. for population-level mammography image quality improvement initiatives at Leeds Teaching Hospitals NHS Trust

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Mammography Image Quality (IQ)

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- The 3 core PHE standards in screening:
  1. Achieve **optimum image quality**
  2. Limit radiation dose
  3. Minimise the number of repeat examinations

^Co-dependent: ↑ image quality = ↓ radiation dose[O'Leary, 2011] & ↓ technical recall[Salkowski, 2019]

- Higher quality images …
  - … ↑ sensitivity[Taplin, 2002]
  - … ↓ stage at detection[Rauscher 2013]
  - … ↓ interval cancers[Taplin, 2002]
  - … ↓ false positive rate[Guertin 2018]

- The $$$ of mammography IQ
  - Annual direct costs:
    - Technical recalls (2.13%[2018-2019]) = **~£1.8 million**
    - QA self-reviews (1 shift/month, 40 studies) = **~£2.5 million**
  - Delayed diagnosis and treatment costs
    - Breast cancer stage = strongest predictor of costs.[Hall 2015]
    - **True annual £ unknown**

Current State of IQ @ LTHT

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- IQ monitoring
  - Technical recall/repeat aggregate rates monitored monthly
- Self-evaluations
  - Screening service: 40 mammograms self-reviewed monthly
  - Diagnostic service: no mandated reviews
- IQ improvement initiatives
  - No active IQ educational interventions
  - Until now, population-level IQ data inaccessible
  - Prospective trial planning

Alignment with NHS mandates

- NHS Long Term Plan for Cancer
  - Calls for improvement in national screening programmes through investment in innovative technologies;
- NHSX Strategic priorities
  - Calls for introducing technologies reducing burden on clinicians and staff, to focus on patients

IQ Assessment Challenges

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- Time-consuming
  - Infeasible at time of image acquisition (8 min/exam)
  - Delayed feedback/corrective action

← Resource challenges further intensified by mammography workforce pressures

- Visual
  - Subjective

UK NHS positioning evaluations

- Nipple in profile
- MLO Pectoral muscle to nipple level
- MLO Pectoral muscle at appropriate angle
- Symmetrical images
- MLO IMF shown clearly
- CC Medial border demonstrated
- CC Some axillary tail shown
- CC Back of breast clearly shown with some medial central & lateral

Some apply literally, others say yes, only when obstructs breast tissue[Boyce 2015]

Ambiguous terms

Does the Pectoralis muscle extend within 1cm of the PNL?

1st read: **9**/15 reviewers = YES
2nd read: **9**/15 reviewers = YES, BUT…

6/15 (40%) reviewers flipped their assessment (3 flipped to present, 3 flipped to absent) [Sharma 2020]

Research Study Objectives

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Primary: To investigate the current state of mammo IQ in breast imaging services at Leeds Teaching Hospitals NHS Trust (n~60 000 images)

Secondary: To compare the population-based AI prevalence rate with visual prevalence rates in a validation sample (n~200 images).

- *The study was waived by research ethics*
- *The study was approved by institutional quality committee*

Methodology

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- Population-based image processing
  - Densitas® IntelliMammo™ was installed
  - Studies acquired over 12/2021 to 03/2022 were processed
    - [N=59 264 images (n_{CC}=29964 n_{MLO}=29300)]
- Manual data collection (random sample of 50 symptomatic studies)
  - A pair of lead radiographers reviewed together for a consensus
  - 196 images (98 CC & 98 MLO)
- Analysis
  - Event rate per positioning error (stratified by CC/MLO)
  - Weekly average error rate time plots
  - Agreement assessed by Cohen's kappa (validation dataset [n=198])

***Kappa Classifications:**
Less than chance agreement (<0);
Slight agreement (0.01-0.20);
Fair agreement (0.21-0.40);
Moderate agreement (0.41-0.60);
Substantial agreement (0.61-0.80);
Almost perfect agreement (>0.80)

Results

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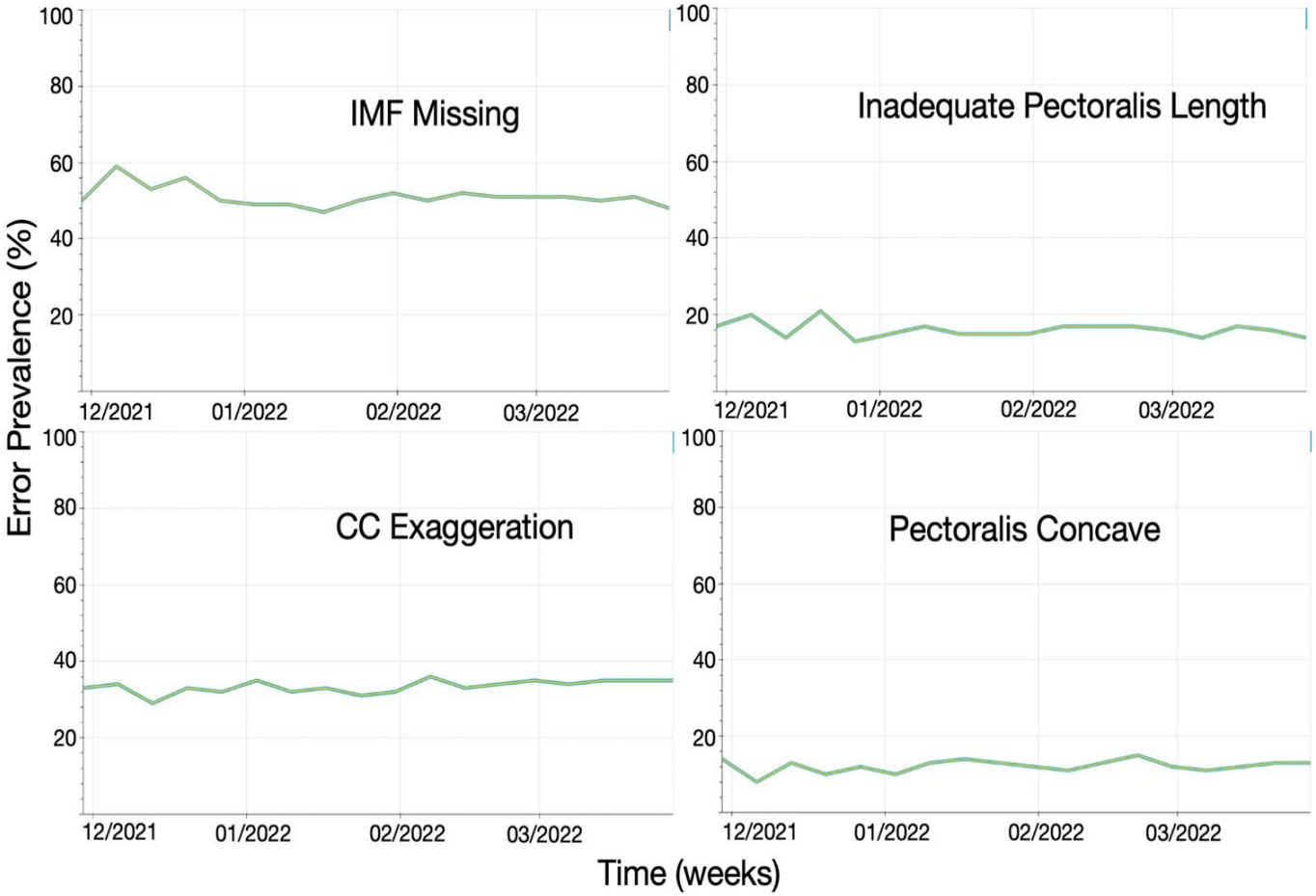
- Population-based error prevalence 12/2021-03/2022
  - As low as **3%** with IR placement error
  - As high as **51%** with IMF missing error
- 3% to 51% by AI in the population-level data, compared to…
  - … 9% to 56% by expert assessment in the validation set
  - … 5.5% to 40.4% by AI assessment in the medical literature
- Kappa range from **'substantial'** (>0.60) to **'almost perfect'** (>0.80)

	Leeds Teaching Hospitals NHS Trust			Medical Literature	
	Population (N=59,264)	Validation set (N=198)			
Positioning Error	**AI Error Rate**	**Expert Error Rate**	**Kappa (95%CI)**	**AI Event Rate**	**Population***
Pectoralis Muscle Length	16%	10%	0.89 (0.69, 1.00)	5.5-37.8%	Norway; Canada
Pectoralis Muscle Concave	13%	12%	0.81 (0.61, 1.00)	16.0-19.2%	Norway
IMF Missing	51%	56%	0.71 (0.51, 0.91)	9.0-20.5%	Norway
IR Placement	3%	9%	0.78 (0.59, 0.98)	--	--
MLO Posterior Tissues Missing	11%	11%	0.85 (0.65, 1.00)	16.1%	Canada
CC Posterior Tissues Missing	23%	12%	0.95 (0.76, 1.00)	20.2%	Canada
CC Excessive Exaggeration	34%	17%	0.70 (0.50, 0.90)	24.4-40.4%	Norway

**Source: Norwegian error rate data [Waade 2021]; *Source: Canadian error rate data [Rouette 2021]*

Weekly rate variation

- **Stable** weekly error rates



← Provides 'baseline' assessment for monitoring improvement initiatives (e.g. educational interventions)

Discussion

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Key findings

- These findings support the use of AI for reliable and reproducible quantitative mammography positioning image quality assessments.
- Aligns with other studies suggesting AI may agree with expert assessments
  - Slight 0.06 (pec shape) to substantial agreement 0.69 (nipple not in profile)[Waade 2021]
- With population-based error rate information at your fingertips, it is possible to evaluate image quality improvement initiatives (such as tailored educational sessions).

Future work

- Investigate Radiographer and Assistant Practitioner error rates
  - Stratification of results by years of experience
- Investigate needs-based image quality improvement initiatives
- Implement interventions and monitor the impacts on baseline error rates
- Stratify error rates by presence of patient associated limitations

Limitations

- Validation data set sample size was small with low positioning error event rates
- Did not stratify analysis by screening and diagnostic mammograms
  - Differences with imaging requirements

Conclusion

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These study findings suggest that automated **A.I.** mammography positioning error assessments may provide a **feasible approach** to **measuring and monitoring** the impact of **image quality improvement initiatives** at Leeds Teaching Hospitals NHS Trust.

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