Intelligence Artificielle au quotidien: Perspectives radiologiques sur la révolution numérique

Patrick Omoumi

Head of Musculoskeletal Radiology
Lausanne University Hospital
Professor at University of Lausanne
Switzerland

UNIL | Université de Lausanne

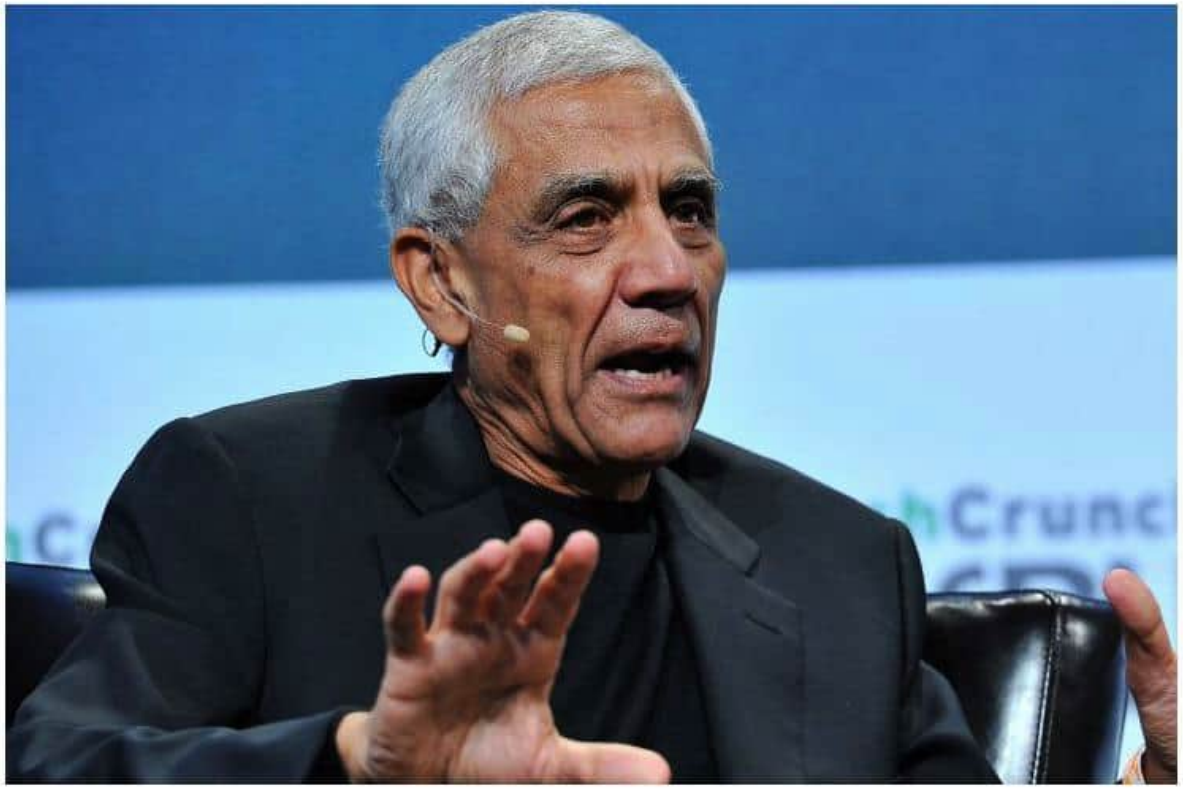
Geoff Hinton. 2016 Machine Learning and Market for Intelligence Conference in Toronto

Here's why one tech investor thinks some doctors will be 'obsolete' in five years

PUBLISHED FRI, APR 7 2017 · 2:28 PM EDT | UPDATED FRI, APR 7 2017 · 5:15 PM EDT

Christina Farr
#CHRISSYFARR

SHARE



"The role of the radiologist will be obsolete in five years"

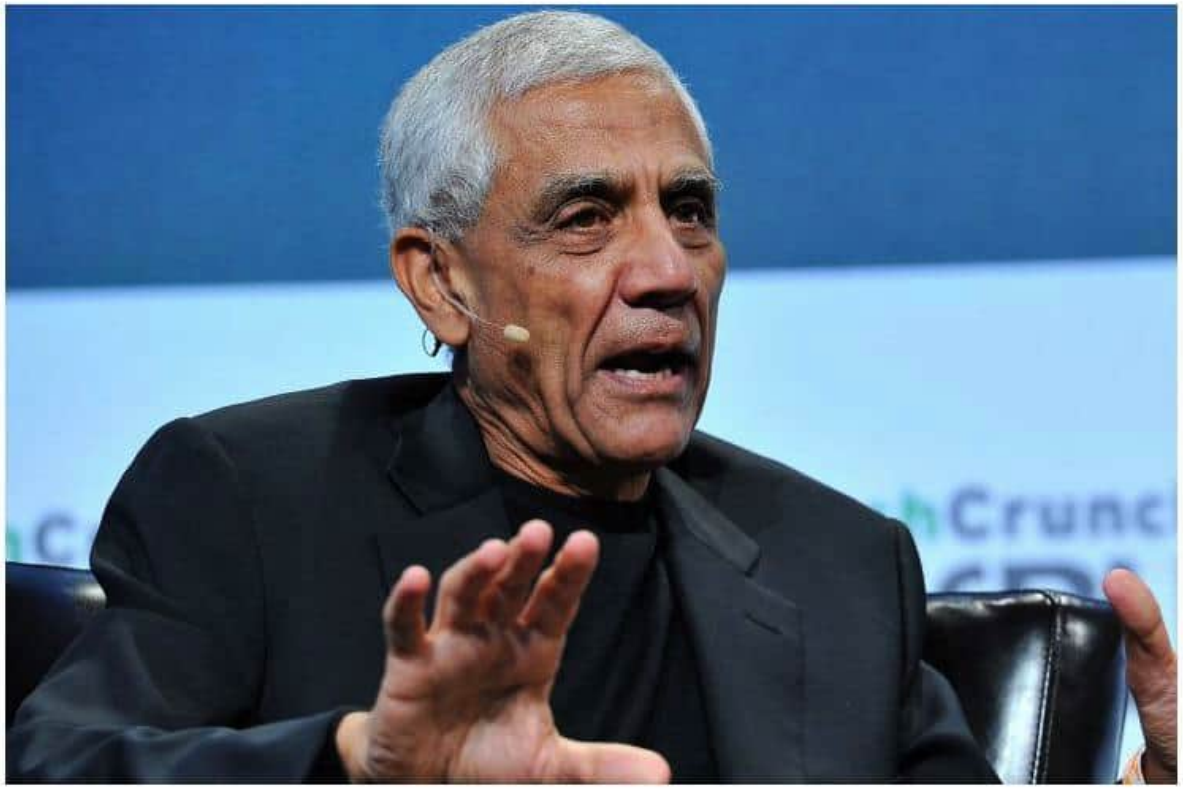
Vinod Khosla, venture capitalist, 2017

Here's why one tech investor thinks some doctors will be 'obsolete' in five years

PUBLISHED FRI, APR 7 2017 · 2:28 PM EDT | UPDATED FRI, APR 7 2017 · 5:15 PM EDT

Christina Farr
#CHRISSYFARR

SHARE



"The role of the radiologist will be obsolete in five years"

Vinod Khosla, venture capitalist, 2017

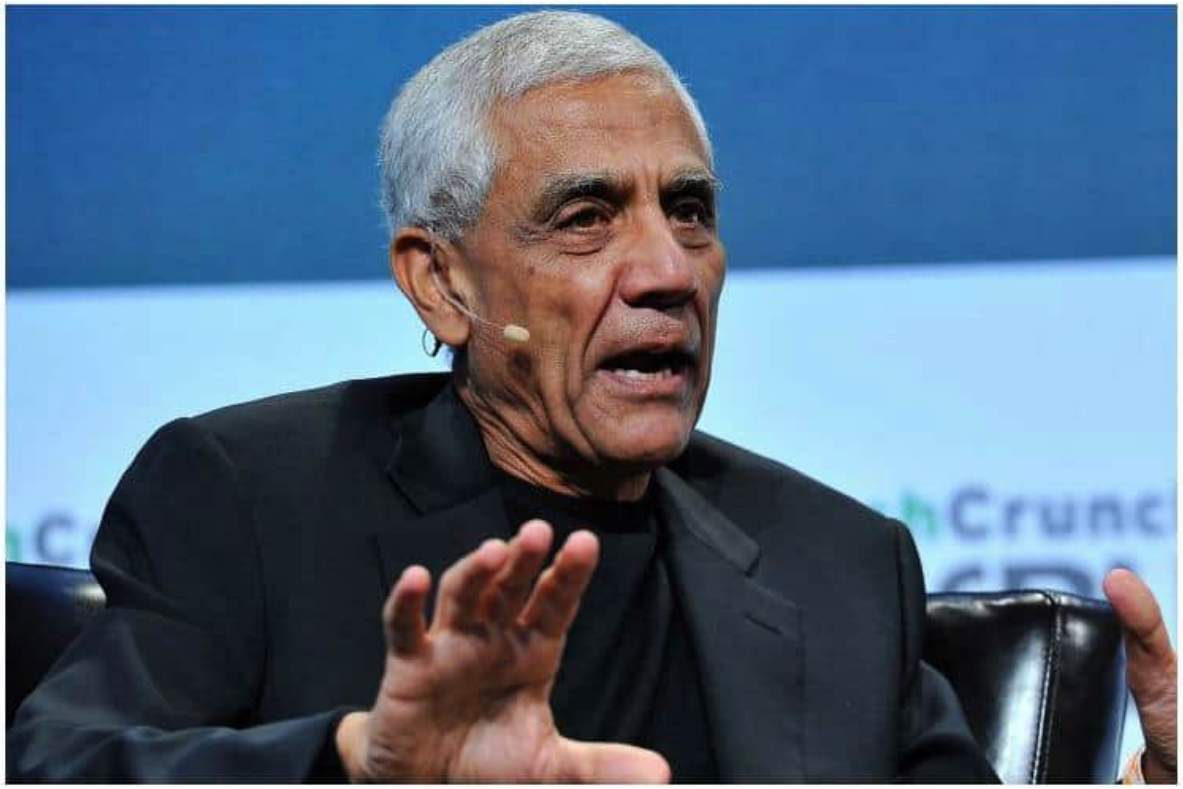
"machines will replace 80 percent of doctors"

Here's why one tech investor thinks some doctors will be 'obsolete' in five years

PUBLISHED FRI, APR 7 2017 · 2:28 PM EDT | UPDATED FRI, APR 7 2017 · 5:15 PM EDT

Christina Farr
#CHRISSYFARR

SHARE



"The role of the radiologist will be obsolete in five years"

Vinod Khosla, venture capitalist, 2017

"machines will replace 80 percent of doctors"

Radiologists say their jobs will only become more important in the coming years.

Threat to jobs

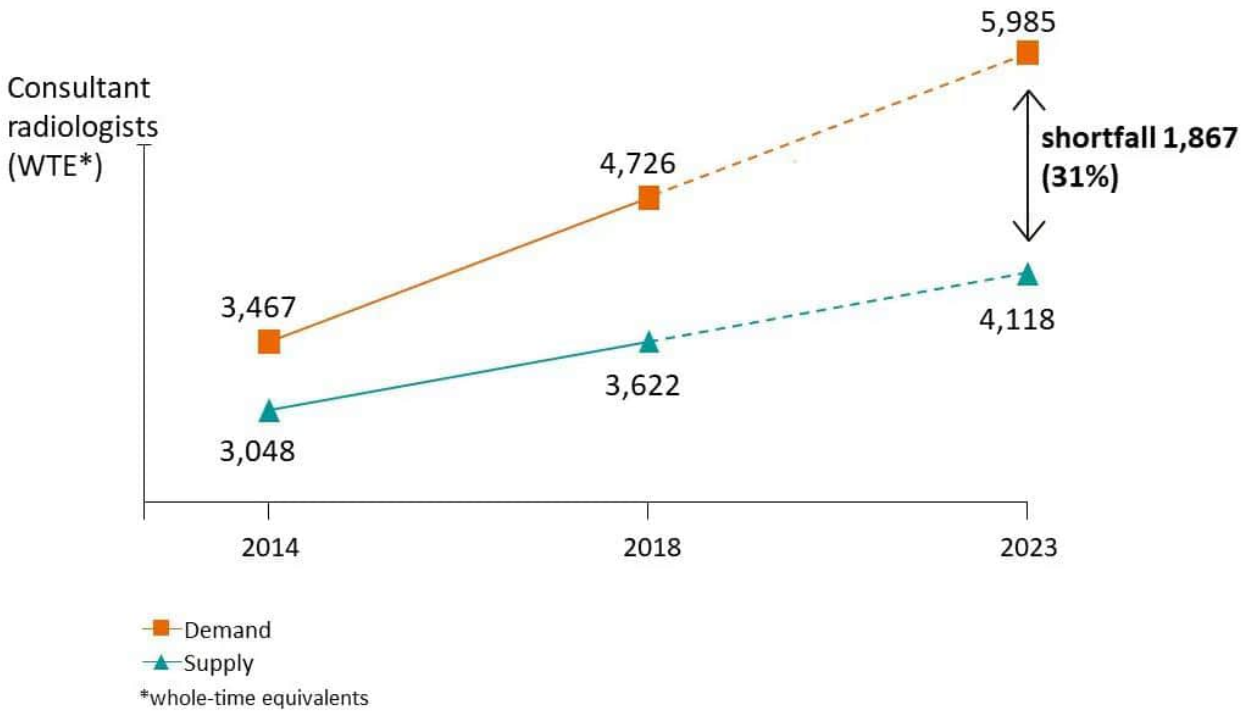
- Andrew Ng (expert in AI at Stanford)

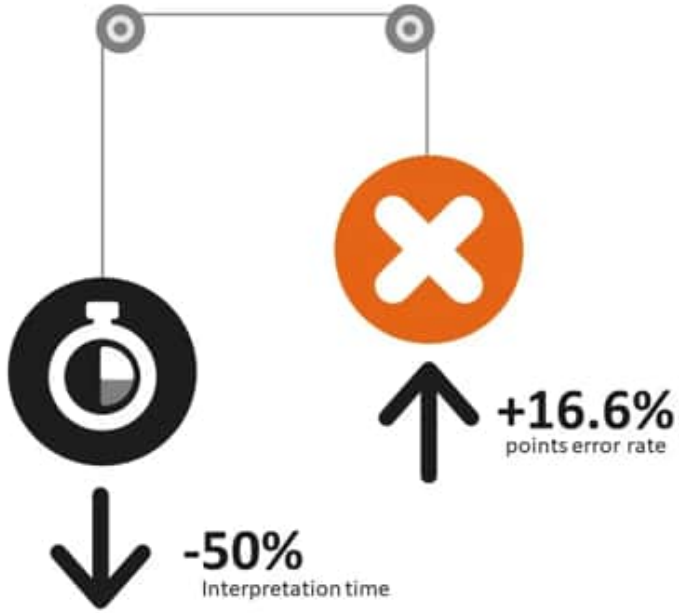
"computers: threat in taking away the job of clinical radiologists" (2018)

- Ezekiel Emanuel (American oncologist, known for his role in the Affordable Care Act) "we will see the first computers replace radiologists within the next 4–5 years" (2016, articles in N Engl J Med and J Am Coll Radiol)

Artificial intelligence in radiology: how will we be affected? S. H. Wong, H. Al-Hasani, Z. Alam, A. Alam. European Radiology 2019


One Image, Every Two Seconds
Of Every Working Day
For an Entire Year
800M
Exams
94B
Images
31K
Radiologists
©2017 International Business Machines





Less interpretation time means the potential for higher error rates

SIEMENS Healthineers

Modern radiology has no alternative but to seek for productivity

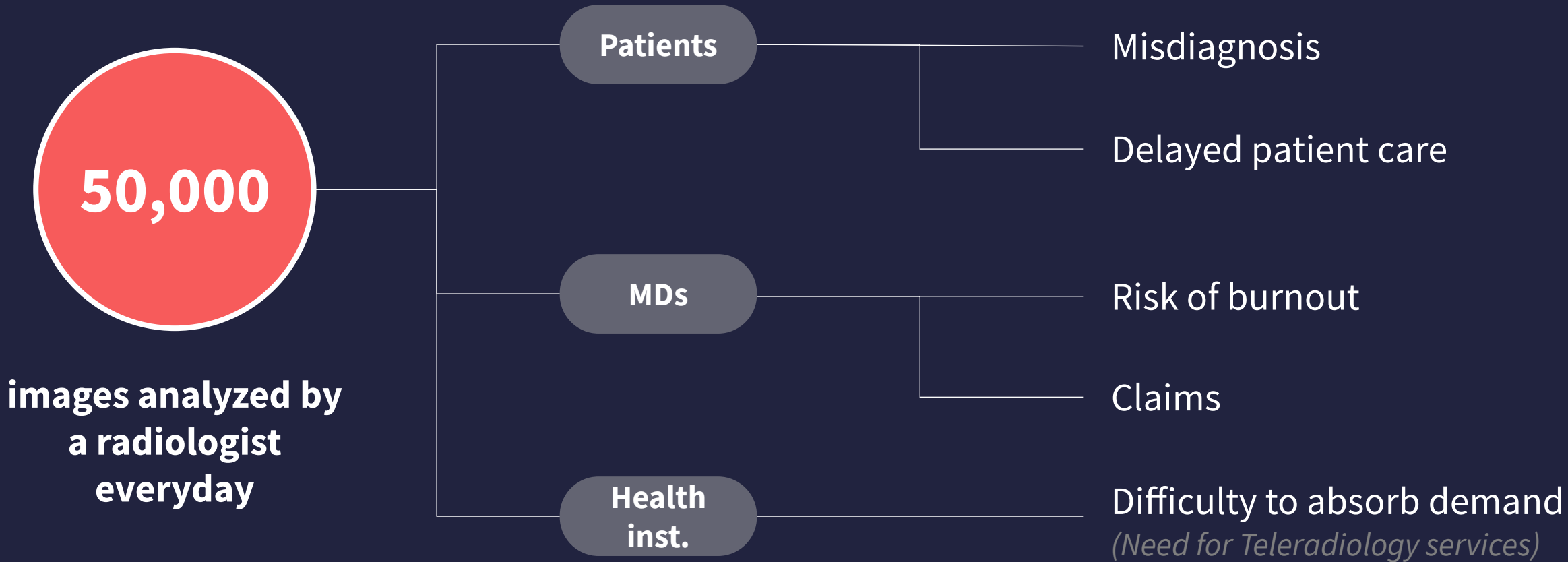
Exploding demand *vs.* Limited radiologist workforce

+100% *vs.* **+20%** *Over the last decade*

High Fixed-Cost structure

Growing pressure on prices

Curbed by the limits of radiologists' capacities. With downsides.



AI can take Radiology past this ceiling: A two-fold promise

1

Secure diagnosis

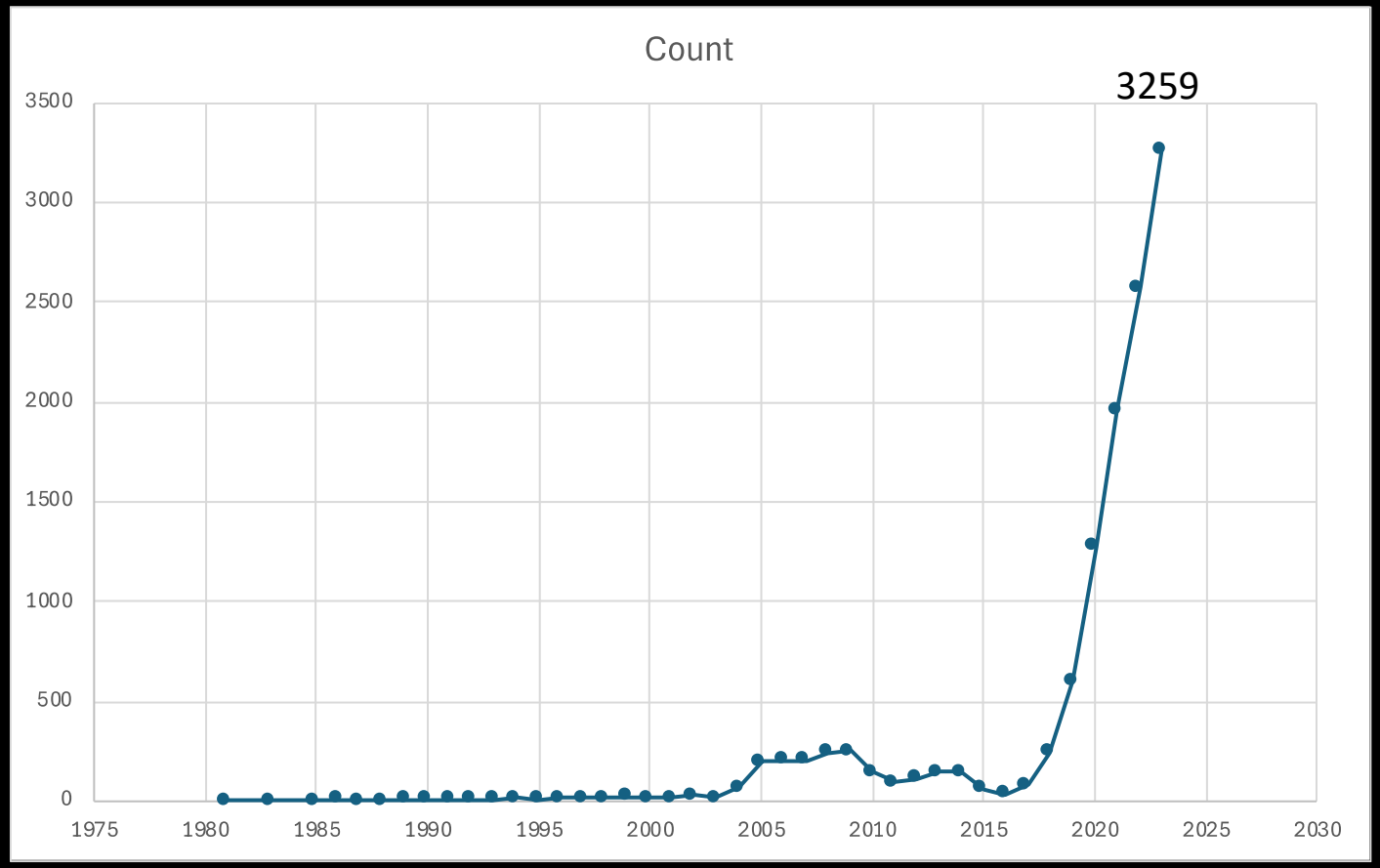
2

Speed up image analysis and overall workflow

Objective

- How can AI impact the radiologist workflow?
- Where are we in 2024? And why?

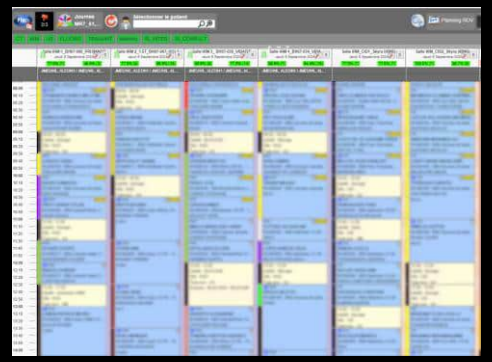
Pubmed (“artificial intelligence” AND “radiology”)



Radiologists' workflow

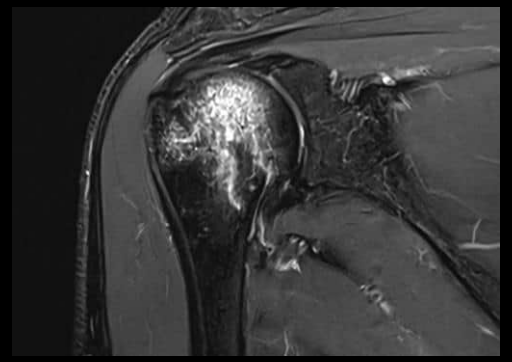
Request → Managing the request and scheduling → Production of images (Protocoling Acquisition Reconstruction) → Image interpretation → Report

Clinician Radiologist



Secretary Radiologist

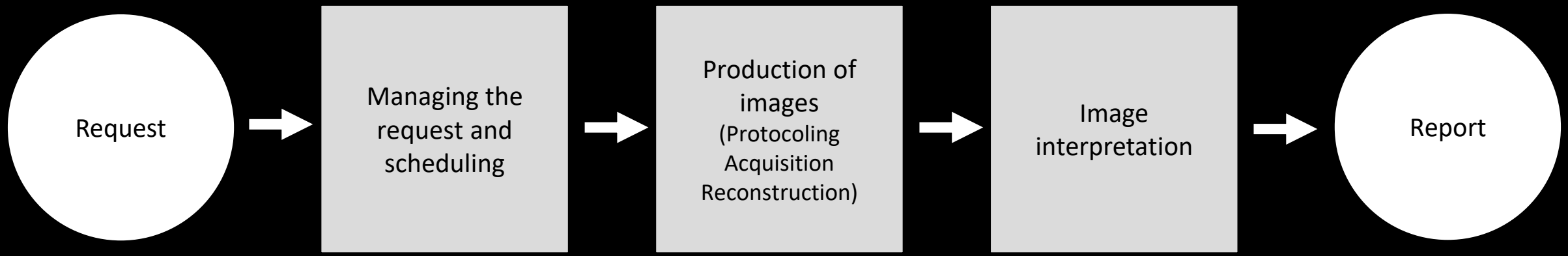
Technician Radiologist

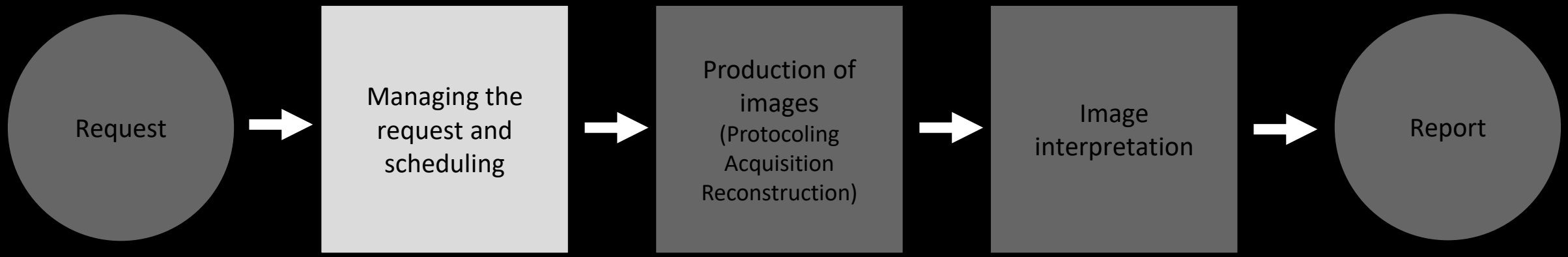


Radiologist

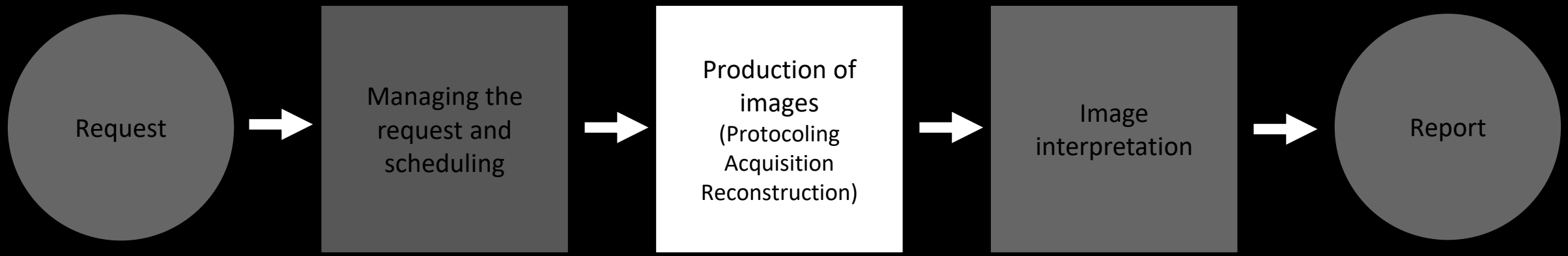
Radiologist

Radiologists' workflow





Pertinent patient information (allergies, devices)
--> Automatic scheduling



Intravenous contrast?
Which protocol?

Natural language processing (NLP)

Fig. 2 Word cloud demonstrating the most commonly found words in the free-text clinical indication. Numbers and punctuation were removed, and each word was converted to its radical form for traditional natural language processing methods

- free text clinical indication of the study
- Accuracy of 83%

- Since then: advent of LLM and Foundation Models…

Trivedi H, Sohn JH. *J Digit Imaging* **(2018)**

Natural language classifier

Journal of Digital Imaging (2018) 31:604–610
https://doi.org/10.1007/s10278-018-0066-y

CrossMark

Efficiency Improvement in a Busy Radiology Practice: Determination of Musculoskeletal Magnetic Resonance Imaging Protocol Using Deep-Learning Convolutional Neural Networks

Young Han Lee[1]

Published online: 4 April 2018

Lee YH. *J Digit Imaging* **(2018)**

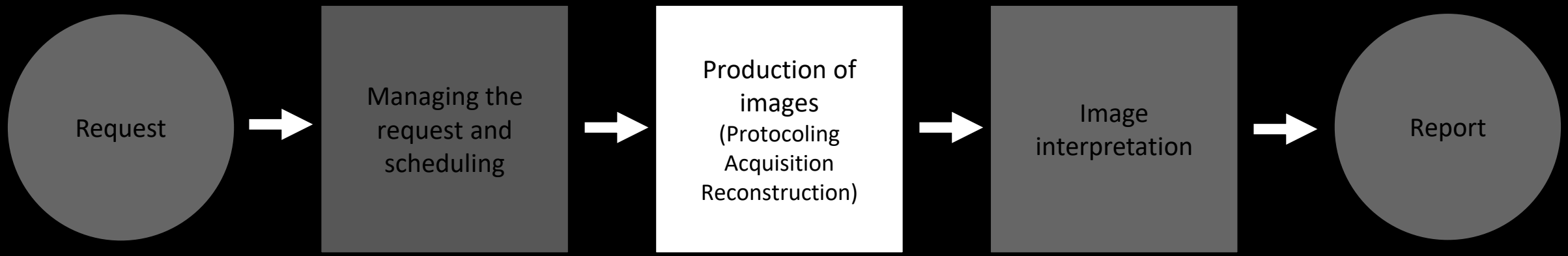
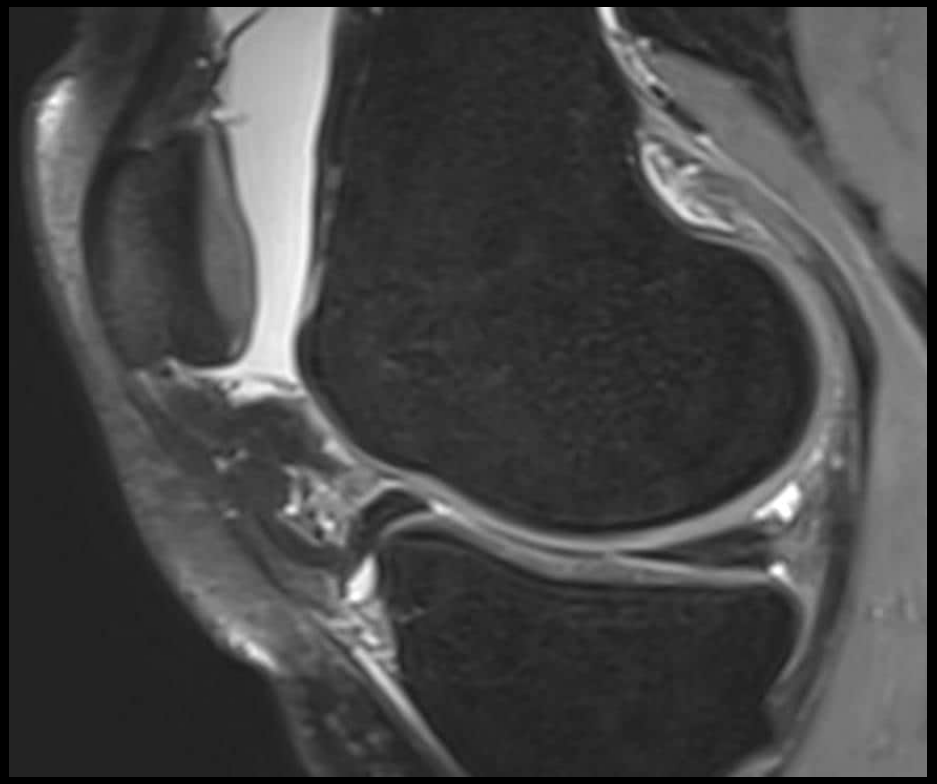
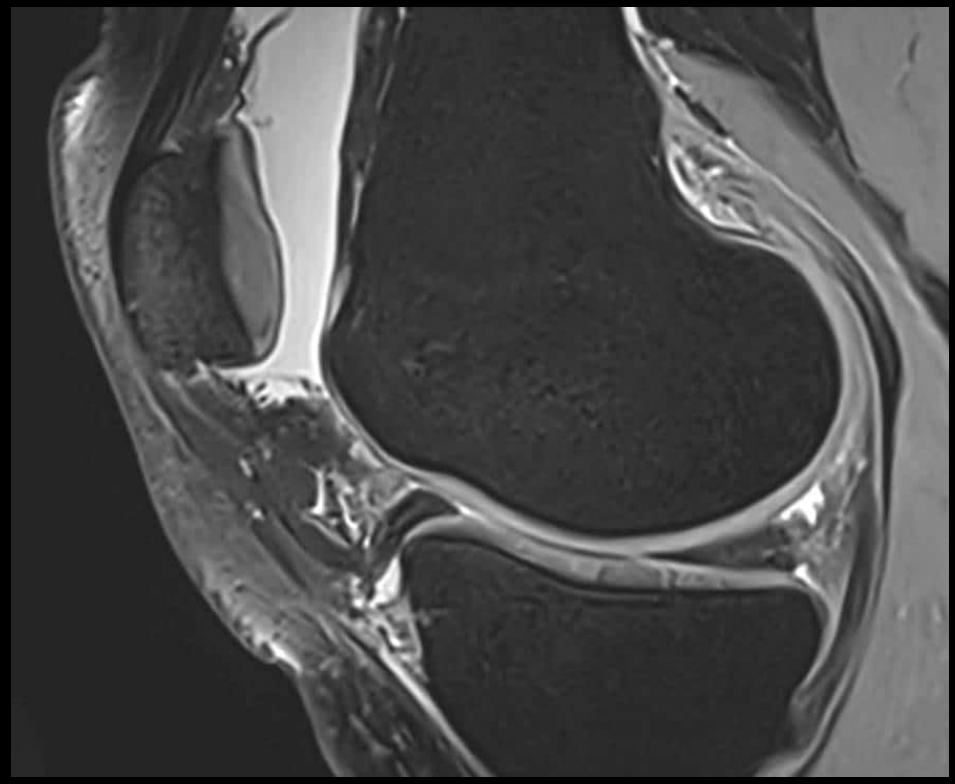


Image Production

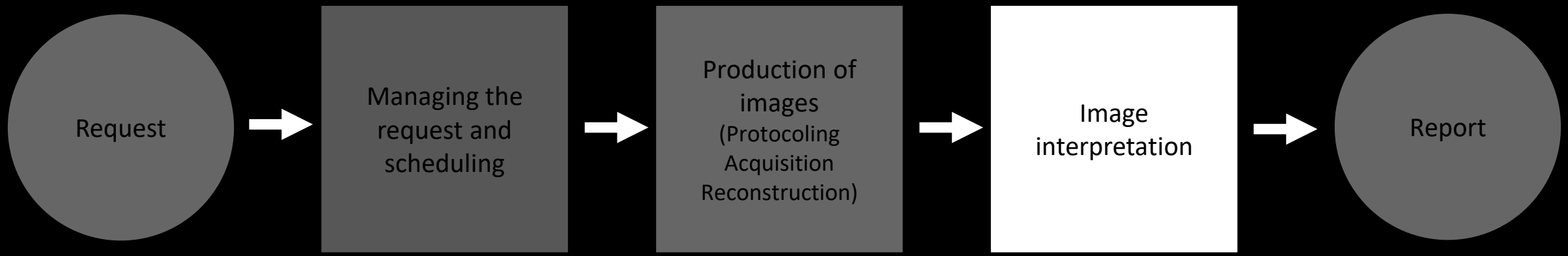
Generative models



6 min



4 min


Request
Managing the request and scheduling
Production of images (Protocoling Acquisition Reconstruction)
Image interpretation
Report

Lesion detection

- Reduction in misinterpretation of *average* emergency medicine clinicians by 47%

Lindsey R, Potter H. Proc Natl Acad Sci U S A (2018)

Lesion detection

- Other applications
  - Flagging urgent exams for urgent care
  - Flagging positive exams for optimized workflow
  - 24/7 service in remote areas
  - …

Lindsey R, Potter H. Proc Natl Acad Sci U S A (2018)

European Radiology (2021) 31:3786–3796
https://doi.org/10.1007/s00330-020-07684-x

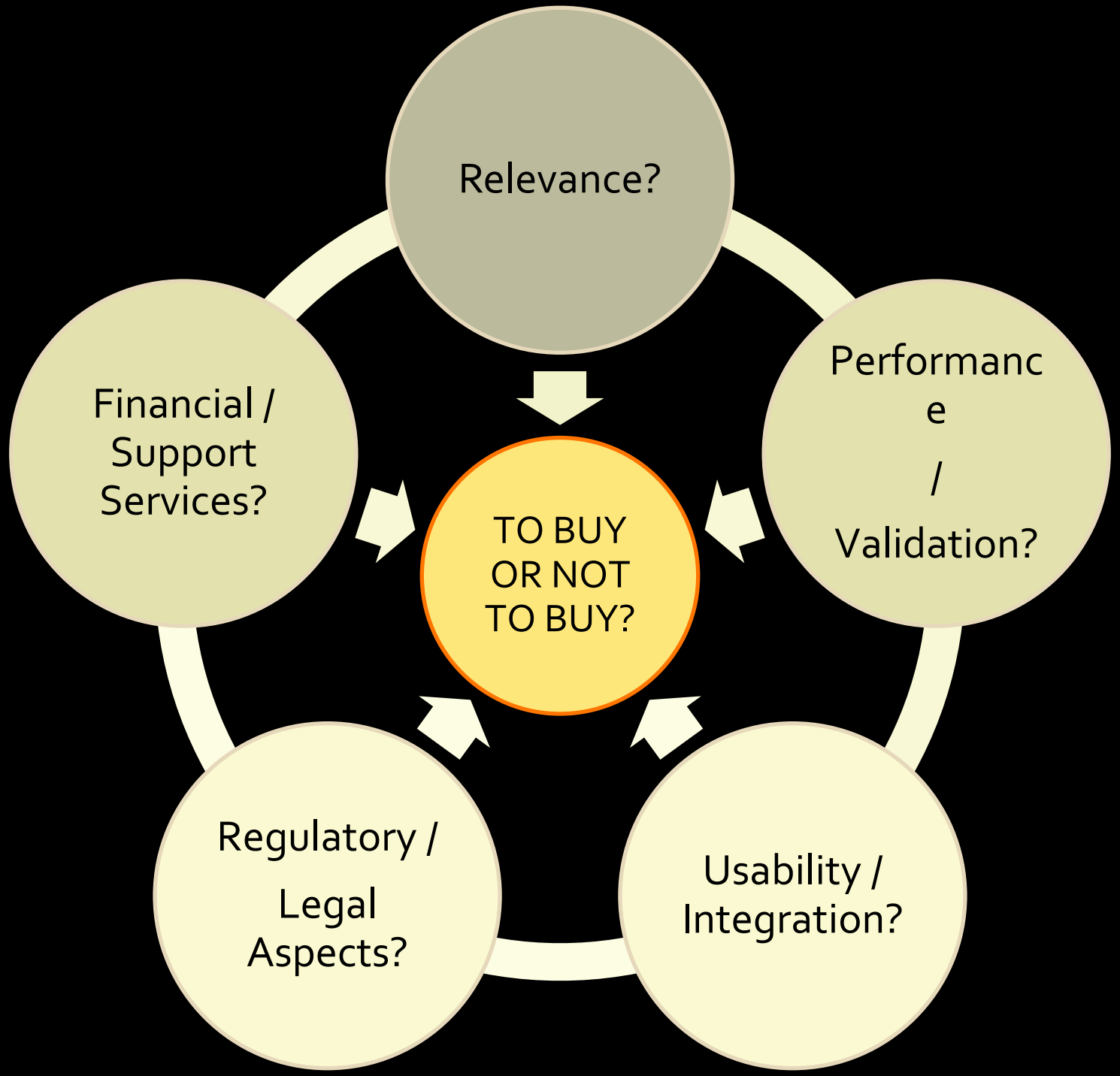
IMAGING INFORMATICS AND ARTIFICIAL INTELLIGENCE

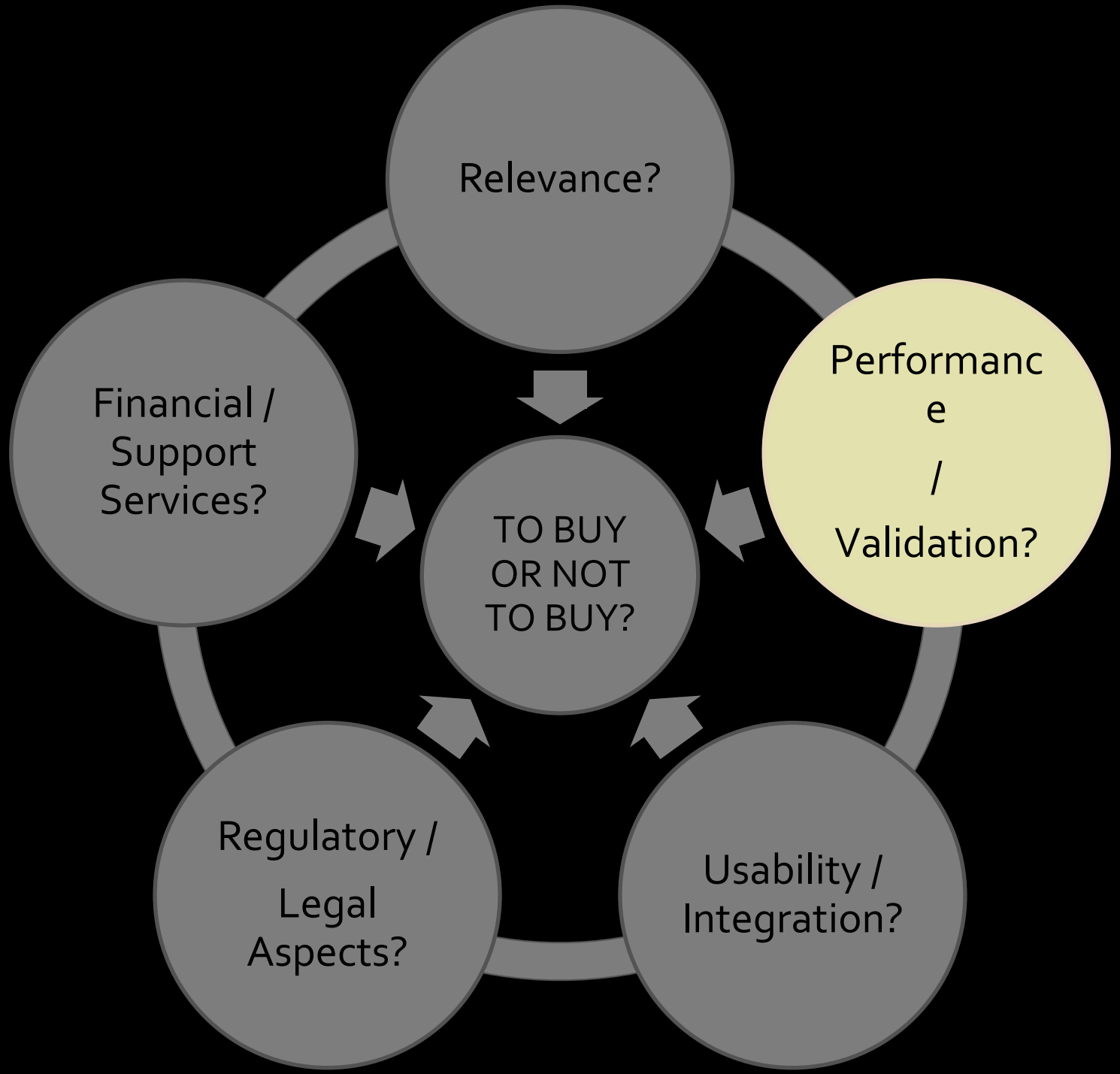
To buy or not to buy—evaluating commercial AI solutions in radiology (the ECLAIR guidelines)

Patrick Omoumi[1] · Alexis Ducarouge[2] · Antoine Tournier[2] · Hugh Harvey[3] · Charles E. Kahn Jr[4] · Fanny Louvet-de Verchère[5] · Daniel Pinto Dos Santos[6] · Tobias Kober[7] · Jonas Richiardi[1]

Received: 6 November 2020 / Revised: 9 December 2020 / Accepted: 29 December 2020 / Published online: 5 March 2021

1. Relevance	**1.1. What problem is the application intended to solve, and who is the application designed for?** *Define the scope of application; end-users; research vs. clinical use; usage as double reader, triage, other; outputs (diagnosis, prognosis, quantitative data, other), indications and contra-indications* **1.2 .What are the potential benefits, and for whom?** *Consider benefits for patients, radiologists/referring clinicians, institution, society* **1.3. What are the risks associated with the use of the AI system?** *Consider risks of misdiagnosis (including legal costs), of negative impact on workflow, of negative impact on quality of training*
2. Performance and validation	**2.1. Are the algorithm's design specifications clear?** *Check robustness to variability of acquisition parameters; identify features (radiomics) or network architecture (deep learning) used* **2.2. How was the algorithm trained?** *Assess population characteristics and acquisition techniques used, labeling process, confounding factors, and operating point selection* **2.3. How has performance been evaluated?** *Check proper partitioning of training/validation/testing data, representativeness and open availability of data. Assess human benchmarks, application scope during evaluation, source of clinical validation* **2.4. Have the developers identified and accounted for potential sources of bias in their algorithm?** *Assess training data collection, bias evaluation, stratification analyses* **2.5. Is the algorithm fixed or adapting as new data comes in?** *Check whether user feedback is incorporated, if regulatory approval is maintained, and if results are comparable with previous versions. **
3. Usability and integration	**3.1. How can the application be integrated into your clinical workflow?** *Consider integration with your information technology (IT) platform, check for compliance with ISO usability standards, consider issues related to practical management of the software* **3.2. How exactly does the application impact the workflow?** *Identify modifications to bring to your current workflow, identify roles in the new workflow (physicians and non-physicians)* **3.3. What are the requirements in terms of information technology (IT) infrastructure?** *Consider on-premise vs. cloud solutions. Identify requirements in terms of hardware and network performance, consider network security issues* **3.4. Interoperability - How can the data be exported for research and other purposes?** *Check whether the export formats are suitable* **3.5. Will the data be accessible to non-radiologists (referring physicians, patients)?** *Check whether the form of the output is suitable for communication with patients/referring physicians* **3.6. Are the AI model's results interpretable?** *Check whether and which interpretability tools (i.e. visualization) are used*
4. Regulatory and legal aspects	**4.1. Does the AI application comply with the local medical device regulations?** *Check whether the manufacturer obtained regulatory approval from the country where the application will be used (CE, FDA, UKCA, MDSAP, or other local guidance), and for which risk class* **4.2. Does the AI application comply with the data protection regulations?** *Check whether the manufacturer complies with local data protection regulations and provides contractual clauses protecting patient's data*
5. Financial and support services	**5.1. What is the licensing model?** *Assess one-time fee vs. subscription models, total costs, scalability* **5.2. How are user training and follow-up handled?** *Check whether training sessions are included and at which conditions further training can be obtained* **5.3. How is the maintenance of the product ensured?** *Check whether regular maintenance is included, assess the procedure during downtime and for repair* **5.4. How will potential malfunctions or erroneous results be handled?** *Assess the procedure in the event of malfunction and post market surveillance and follow-up*


Relevance?
Performanc
e
/
Validation?
Usability /
Integration?
Regulatory /
Legal
Aspects?
Financial /
Support
Services?
TO BUY
OR NOT
TO BUY?


Relevance?
Performanc
e
/
Validation?
Usability /
Integration?
Regulatory /
Legal
Aspects?
Financial /
Support
Services?
TO BUY
OR NOT
TO BUY?

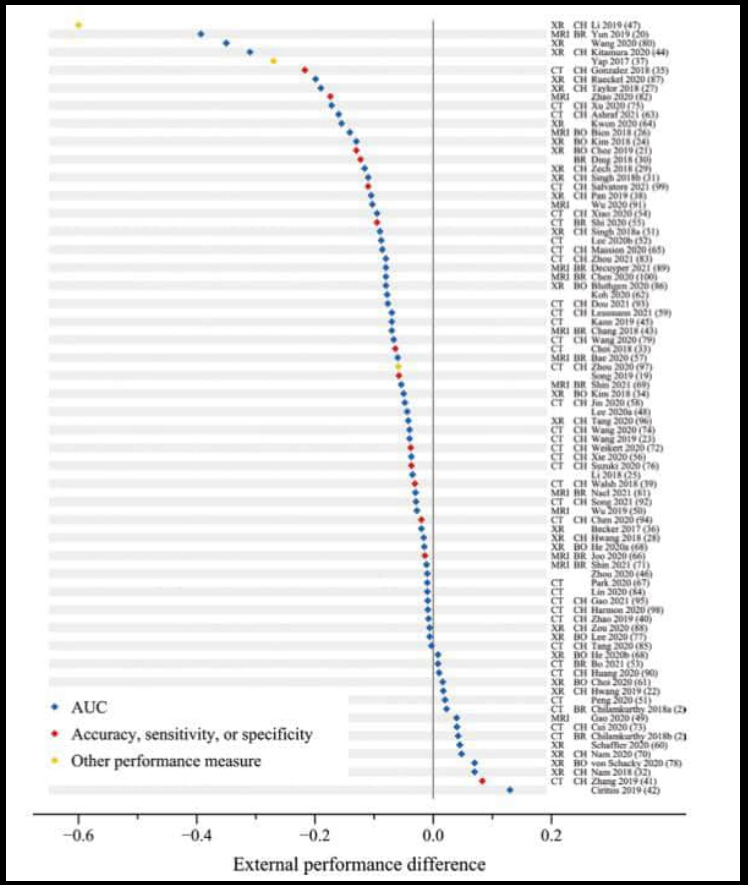
What is the situation of the market?

- *% of studies performing external validation:*
  - *6% (AI application in medical imaging)*

Kim DW et al., Park SH. *Korean Journal of Radiology* (2019)

  - *10% (AI applications in neuroimaging)*

Yao AD et al., Kitamura F. Radiol Artif Intell (2020)



Vast majority: decrease in external performance compared to internal performance

Yu AC et al., Eng J. *Radiol Artif Intell* (2022)

Wh et?

- *"Only 36 have pee evidence studies de levels of e*

European Radiology (2022) 32:7998–8007
https://doi.org/10.1007/s00330-022-08784-6

IMAGING INFORMATICS AND ARTIFICIAL INTELLIGENCE

Radiology artificial intelligence: a systematic review and evaluation of methods (RAISE)

Brendan S. Kelly[1,2,3,4,6] · Conor Judge[3,5] · Stephanie M. Bollard[3,4] · Simon M. Clifford[1] · Gerard M. Healy[1] · Awsam Aziz[4] · Prateek Mathur[2] · Shah Islam[7] · Kristen W. Yeom[6] · Aonghus Lawlor[2] · Ronan P. Killeen[1,4]

Received: 11 November 2021 / Revised: 17 March 2022 / Accepted: 26 March 2022 / Published online: 14 April 2022

Abstract

Objective There has been a large amount of research in the field of artificial intelligence (AI) as applied to clinical radiology. However, these studies vary in design and quality and systematic reviews of the entire field are lacking.This systematic review aimed to identify all papers that used deep learning in radiology to survey the literature and to evaluate their methods. We aimed to identify the key questions being addressed in the literature and to identify the most effective methods employed.

Methods We followed the PRISMA guidelines and performed a systematic review of studies of AI in radiology published from 2015 to 2019. Our published protocol was prospectively registered.

Results Our search yielded 11,083 results. Seven hundred sixty-seven full texts were reviewed, and 535 articles were included. Ninety-eight percent were retrospective cohort studies. The median number of patients included was 460. Most studies involved MRI (37%). Neuroradiology was the most common subspecialty. Eighty-eight percent used supervised learning. The majority of studies undertook a segmentation task (39%). Performance comparison was with a state-of-the-art model in 37%. The most used established architecture was UNet (14%). The median performance for the most utilised evaluation metrics was Dice of 0.89 (range .49–.99), AUC of 0.903 (range 1.00–0.61) and Accuracy of 89.4 (range 70.2–100). Of the 77 studies that externally validated their results and allowed for direct comparison, performance on average decreased by 6% at external validation (range increase of 4% to decrease 44%).

Conclusion This systematic review has surveyed the major advances in AI as applied to clinical radiology.

Key Points

- *While there are many papers reporting expert-level results by using deep learning in radiology, most apply only a narrow range of techniques to a narrow selection of use cases.*
- *The literature is dominated by retrospective cohort studies with limited external validation with high potential for bias.*
- *The recent advent of AI extensions to systematic reporting guidelines and prospective trial registration along with a focus on external validation and explanations show potential for translation of the hype surrounding AI from code to clinic.*

Keywords Radiology · Artificial Intelligence · Methodology · Systematic reviews

van Leeuwen KG et a

Risks related to biased input data

Risks related to biased input data

CAPTIONS BY

NORMAN AI

INKBLOT #1

Norman sees:

CAPTIONS BY

STANDARD AI

INKBLOT #1

Standard AI sees:

http://norman-ai.mit.edu/#inkblot

Risks related to biased input data

Captions by Norman AI

INKBLOT #1
Norman sees:

Captions by Standard AI

INKBLOT #1
Standard AI sees:

"A GROUP OF BIRDS SITTING ON TOP OF A TREE BRANCH."

http://norman-ai.mit.edu/#inkblot

Risks related to biased input data

Captions by Norman AI

INKBLOT #1

Norman sees:

"A man is electrocuted and catches to death."

Captions by Standard AI

INKBLOT #1

Standard AI sees:

"A group of birds sitting on top of a tree branch."

http://norman-ai.mit.edu/#inkblot

Risks related to biased input data

CAPTIONS BY

NORMAN AI

CAPTIONS BY

STANDARD AI

INKBLOT #8

Norman sees:

"MAN IS SHOT DEAD IN FRONT OF HIS SCREAMING WIFE."

INKBLOT #8

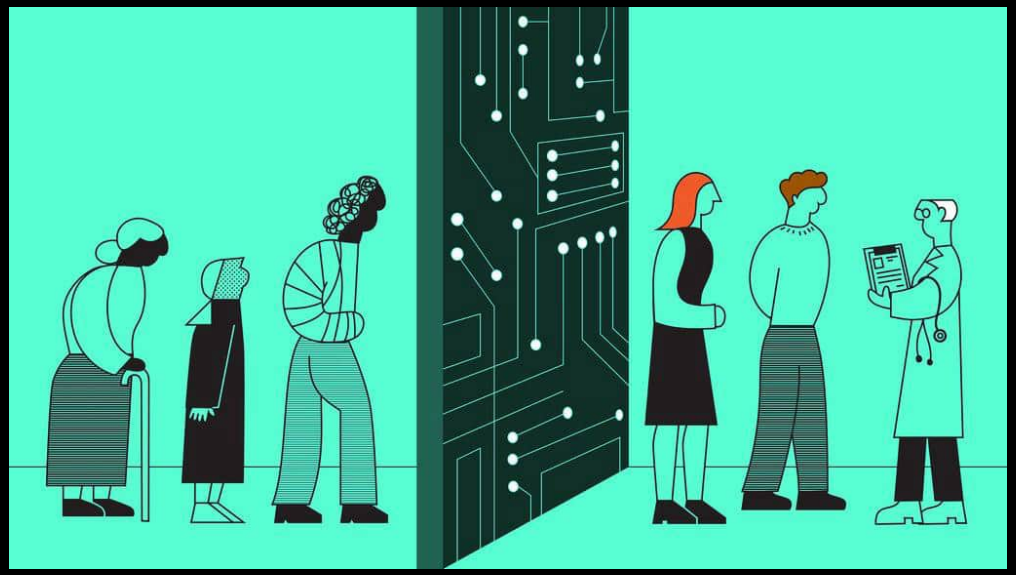
Standard AI sees:

"A PERSON IS HOLDING AN UMBRELLA IN THE AIR."

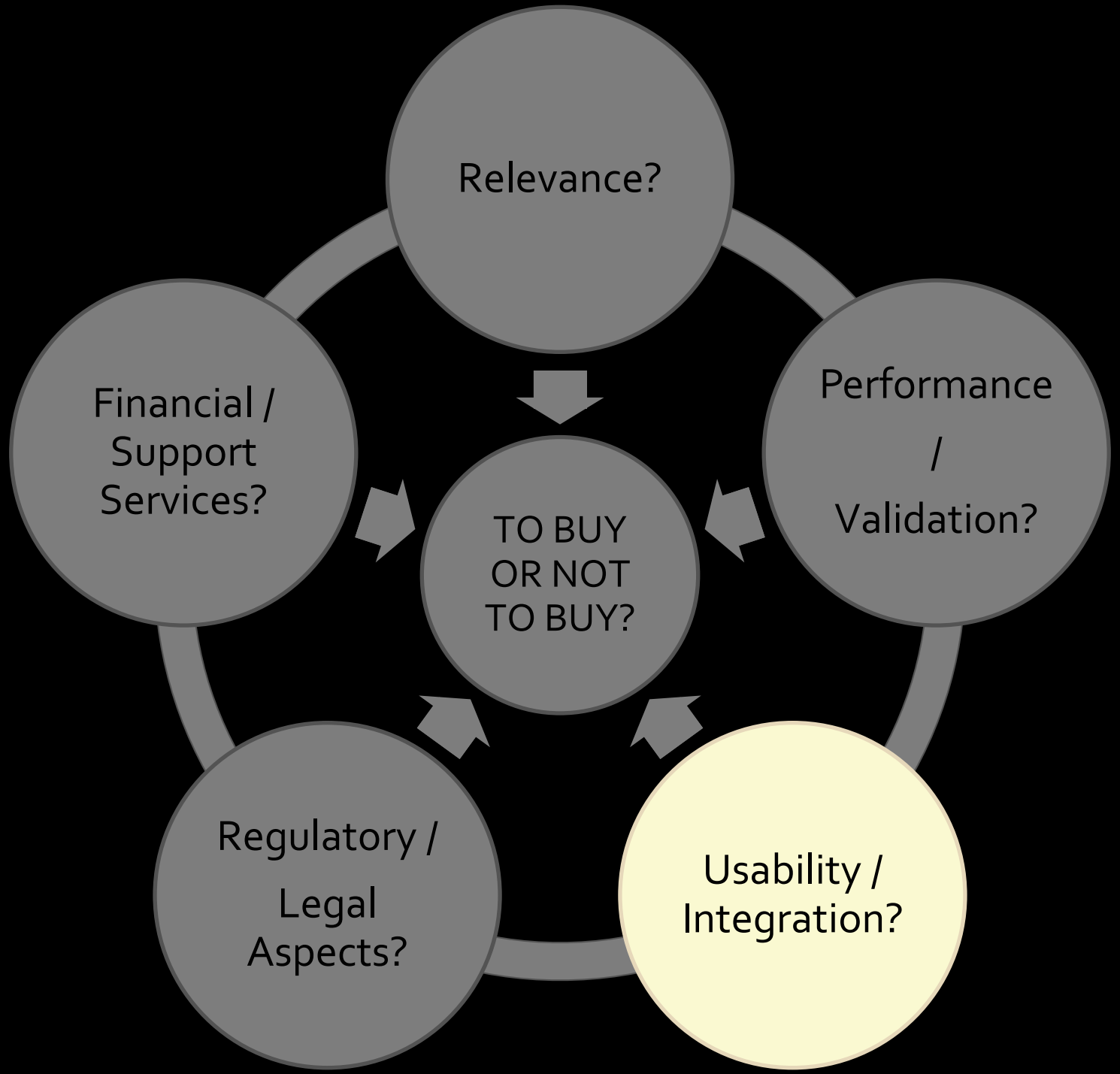
http://norman-ai.mit.edu/#inkblot

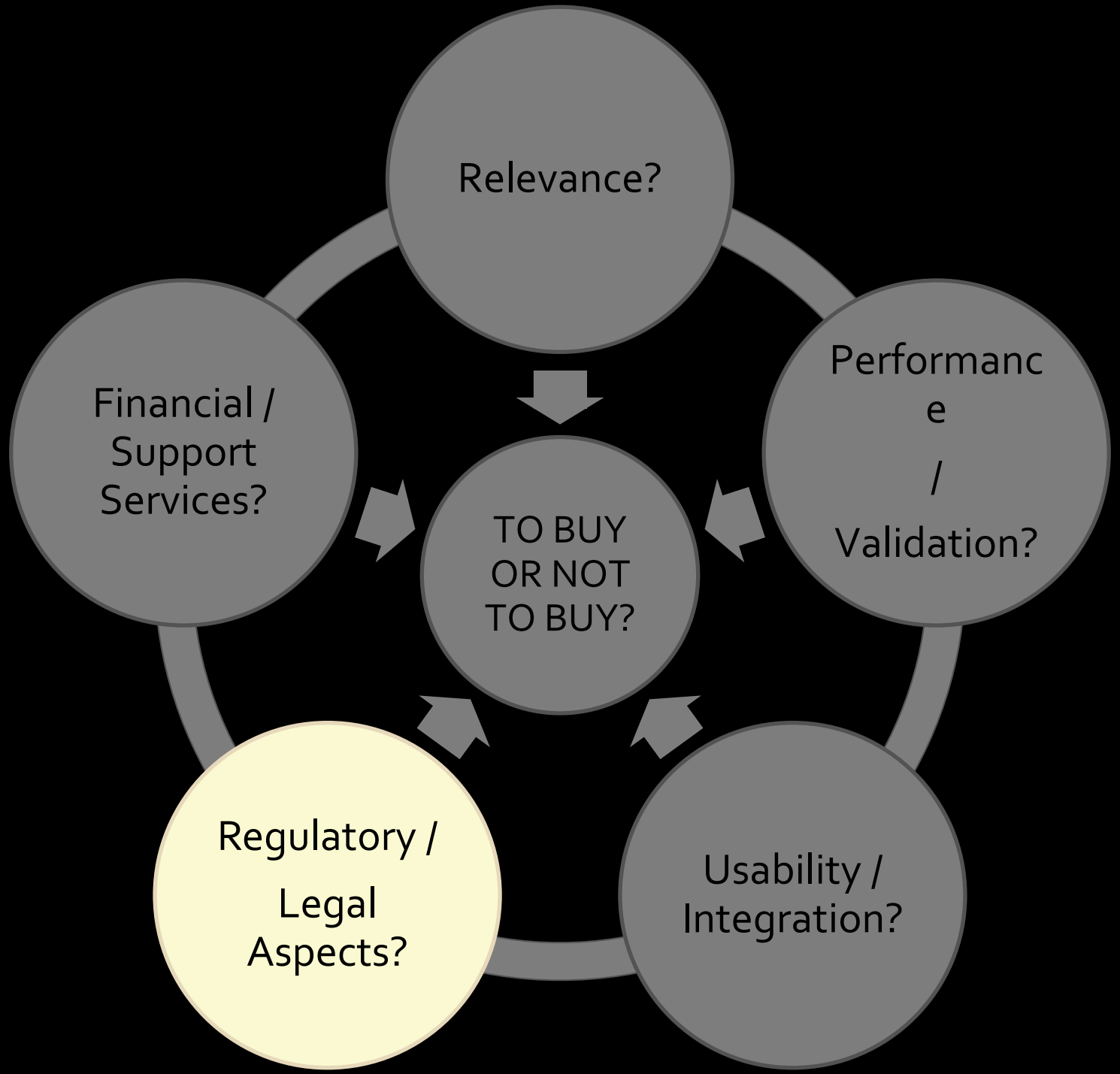
Risks related to biased input data

"If, for example, poorer patients do worse after organ transplantation or after receiving chemotherapy for end-stage cancer, machine learning algorithms may conclude such patients are less likely to benefit from further treatment — and recommend against it."



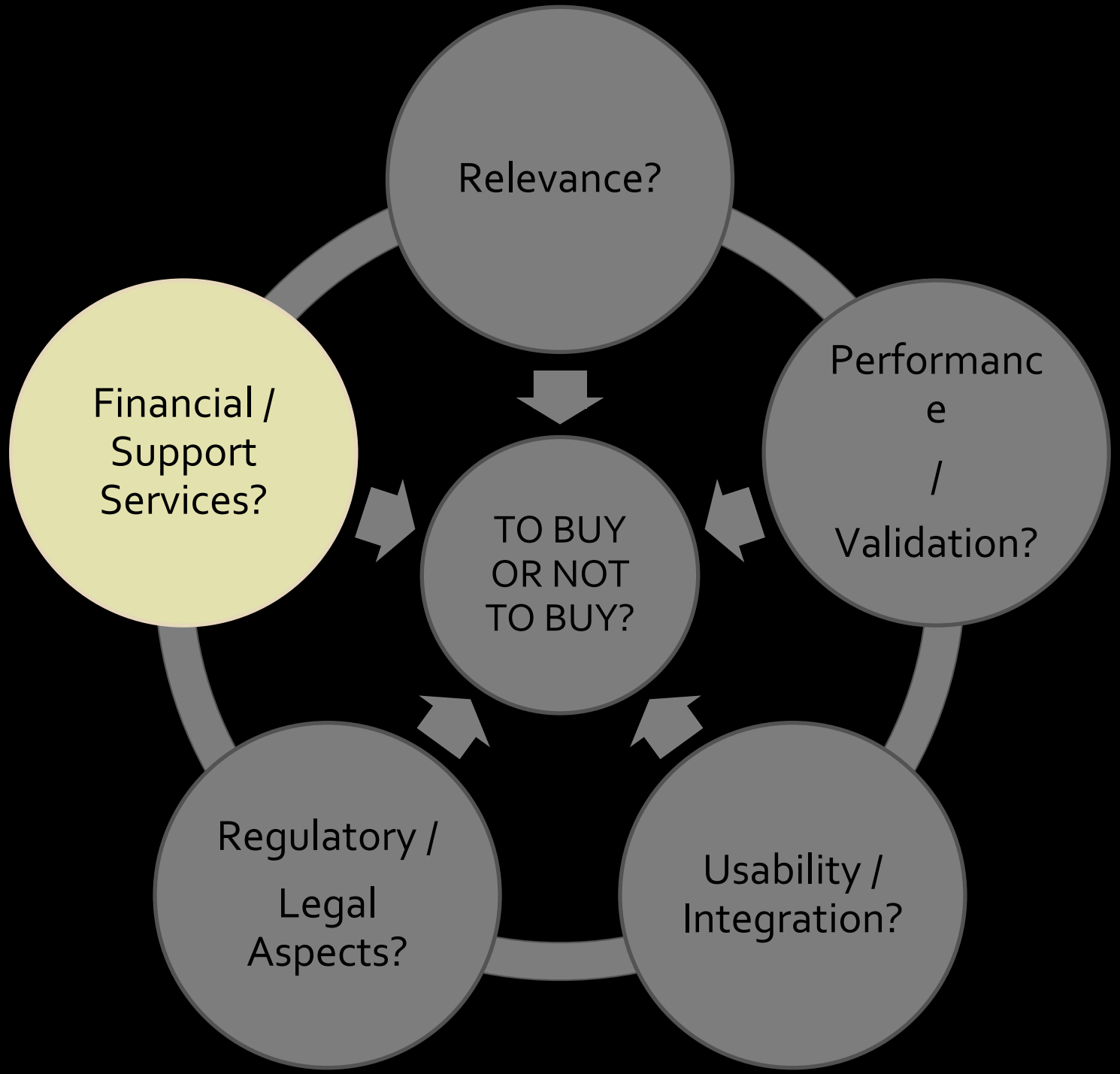
Dhruv Kullar. A.I Could Worsen Health Disparities. New York Times 31 Jan 2019

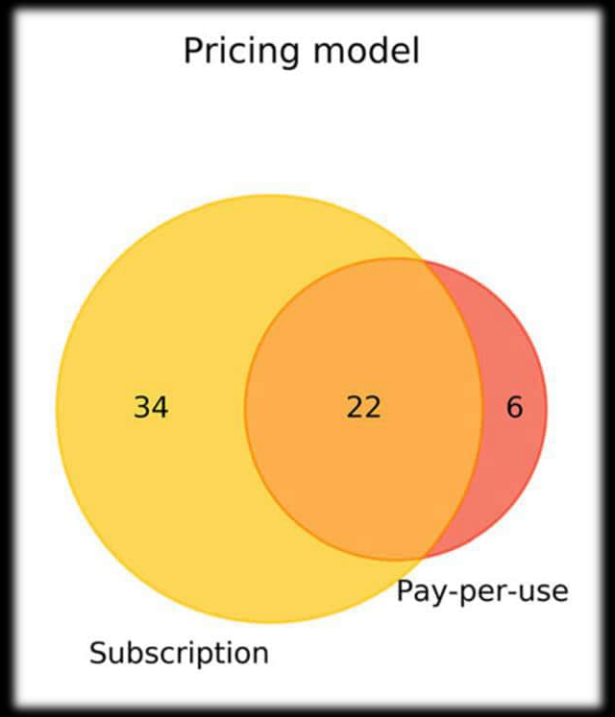

Relevance?
Performance / Validation?
Usability / Integration?
Regulatory / Legal Aspects?
Financial / Support Services?
TO BUY OR NOT TO BUY?


Relevance?
Performanc
e
/
Validation?
Usability /
Integration?
Regulatory /
Legal
Aspects?
Financial /
Support
Services?
TO BUY
OR NOT
TO BUY?

Liability


I'm BEING SUED FOR A MISSED DIAGNOSIS! WHAT DO I DO NOW?!
SORRY, BUDDY, COMES WITH THE JOB.
WHEN HANDING RADIOLOGY OVER TO ARTIFICIAL INTELLIGENCE SOUNDS APPEALING.


Relevance?
Performanc
e
/
Validation?
Usability /
Integration?
Regulatory /
Legal
Aspects?
Financial /
Support
Services?
TO BUY
OR NOT
TO BUY?



van Leeuwen KG et al., de Rooij M. *Eur Radiol* (2021)

$$\frac{\text{Return (Benefit)}}{\text{Investment (Cost)}} = \text{ROI}$$

$$\frac{\text{Return (Benefit)}}{\text{Investment (Cost)}} = \text{ROI}$$

15 July 2020 at 12:26

To: Reto Meuli <reto.meuli@unil.ch>,
Resent-From: Reto.Meuli@unil.ch

Ce message a été archivé.

Dear Dr. Reto Meuli,
On 1 January 2021, the price of your licence will increase by 20%.
To make sure that we continue offering the best possible performance, support, and compliance, we found it necessary to increase the prices. This price change is the first of its kind for since 2012.
The increase in price is due to the EU's Medical Device Regulative, which has put an extra workload on producers of medical devices and software, who now need to expand their activities in quality assurance considerably to conform with the increased demands for documentation and audits.
In addition, software devices like get up-classified from Class I to Class IIa, which adds to the requirements. This also applies for products like which have been on the market for many years and have already demonstrated their safety and efficiency.
The transition to MDR gives many advantages for the clinics and patients, for example:

- Better risk management.
- Better documentation of the product.
- Better documentation of the clinical evaluation, including external audits thereof.
- Better data security.
- Intensified post-market surveillance.

We welcome any question you might have concerning the price changes or concerning in general.
With best regards,

Dear Prof. Meuli,

I am very pleased to personally share this exciting and delightful news with you: _____ is now part of _____. As an independent company with an unchanged product portfolio and customer base, we will continue to be there for you with the contacts you know.

Read on to find out about the outstanding new developments you can look forward to thanks to our collaboration - and that's just the beginning!

Kind regards,

Conclusion

- Radiologists have not been replaced by AI!
- An emerging / unstable market
- One task, one algorithm: you would need thousands of algorithms to replace a radiologist
- Independent validation of performance on external datasets is still missing in most instances
- Importance pour les radiologues de garder les compétences

Siegel 2018 Applied radiology

Conclusion

"One could argue that *Artificial Intelligence*, as it relates to healthcare, should perhaps stand for *Augmented Intelligence*."

Siegel 2018 Applied radiology

Conclusion

"Will AI replace radiologists?" is the wrong question. The right answer is:

Radiologists who use AI will replace radiologists who don't.

Langlotz C, Radiology: artificial intelligence (2019)

Conclusion

“Artificial Intelligence is no match for natural stupidity”

Anonymous

Intelligence Artificielle au quotidien: Perspectives radiologiques sur la révolution numérique

Patrick Omoumi

Head of Musculoskeletal Radiology
Lausanne University Hospital
Professor at University of Lausanne
Switzerland

UNIL | Université de Lausanne