The Benefits of Comprehensive AI Solutions for Medical Imaging

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Contents

Introduction

The need for artificial intelligence is clear. Globally, the volume of scans requiring interpretation is growing at a much greater pace than increases in the numbers of radiologists to read them. One survey, conducted by the Royal College of Radiologists (RCR) in 2016, found that between 2012 and 2015, the number of CT and MRI scans increased by 29% and 26% respectively, while, over the same period, the consultant radiologist workforce grew by only 5%. With radiologists working at, or close to capacity, this bottleneck can only be alleviated by technologies such as AI that can increase the productivity of these radiologists, allowing more reads to be performed by the existing workforce, or to enable radiologists to focus on more complex tasks, while AI tools automate simpler parts of the process. AI algorithms also promise to enable radiologists to manage increasing demands in other ways. From detection and triage tools which alert radiologists to regions of interest, and tools which automate the annotation and quantification of medical images to products which offer suggested diagnoses or predictive analytics, there are myriad ways in which AI technology can have a very significant impact on medical imaging.

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This potential encouraged many companies to expend resources developing AI algorithms for a variety of medical imaging applications. Most of these companies are start-ups, with some now emerging as scale-ups, typically backed by venture capitalists. In many cases these companies are focused on developing algorithms which address a single, specific clinical need, such as the detection of a specific radiological finding (e.g. lung nodule) for a particular scan type (e.g. chest CT). The proliferation of these single-use solutions entering the market is an indication that AI is in the early stages of making the transition from research innovation, to mainstream clinical tool. This transition has also spurred action from incumbent imaging modality and PACS vendors, with some exclusively partnering with specialist AI firms, while others have adopted a 'build and partner' strategy and are selectively developing their own algorithms alongside cherry-picking best of breed algorithms from the AI specialists. All told, there are now more than 200 companies developing AI algorithms for medical imaging.

Figure 1 Funding for medical imaging AI startups tops USD 2.5 billion

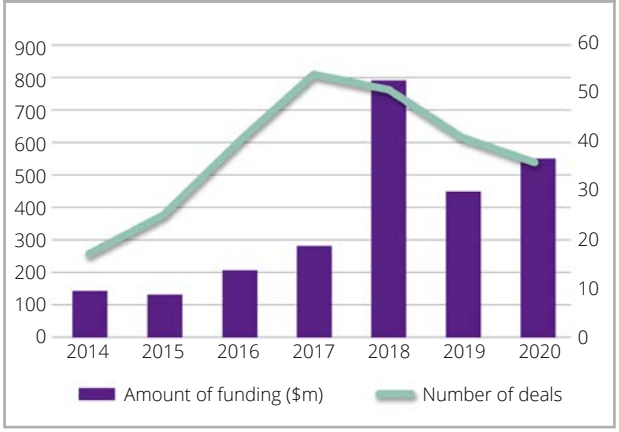
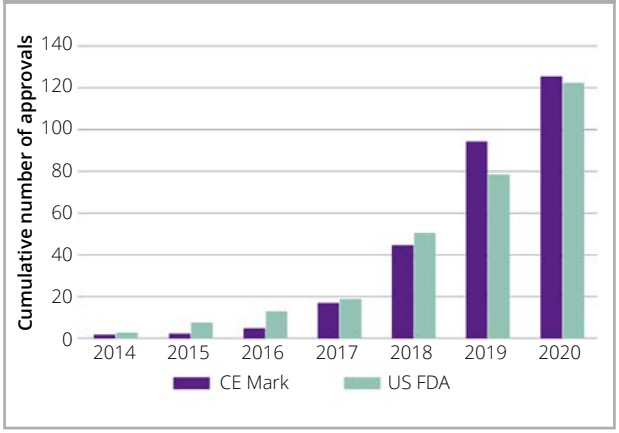


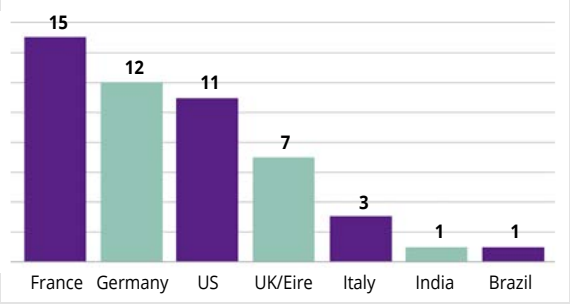
Figure 2 Regulatory approvals for medical imaging AI products



The PACS vendors are also pushing to better incorporate AI tools into their products and bring AI services to radiology workflows. Different vendors are taking different approaches to this incorporation, with some offering dedicated platforms and marketplaces for the selection, deployment and integration of AI algorithms and others working to perfect more custom integrated solutions with a select number of AI partners. Both approaches have merit. Marketplaces, for example, instantly give providers access to a whole host of algorithms from a wide range of vendors and may be particularly suitable for those providers who

NHS case study

Figure 3 Radiologists per 100,000 people in selected countries - 2018



1. The UK has an exceptionally high shortage of radiologists; in 2019 there were an estimated seven radiologists per 100,000 population, which is particularly low compared to Europe (13 radiologists per 100,000 people) and the USA (11 per 100,000).
2. In 2019, there was an estimated shortfall of 1,613 (34%) consultant radiologists. With a fifth of radiologists forecast to retire within the next five years, insufficient trainees entering the profession and ever-increasing scan volumes, the situation is set to get worse.
3. More than two-thirds of radiology departments in the UK say they do not have enough radiologists to provide safe and effective care for patients.

In the coming years, AI will play an increasingly important role in addressing these issues.

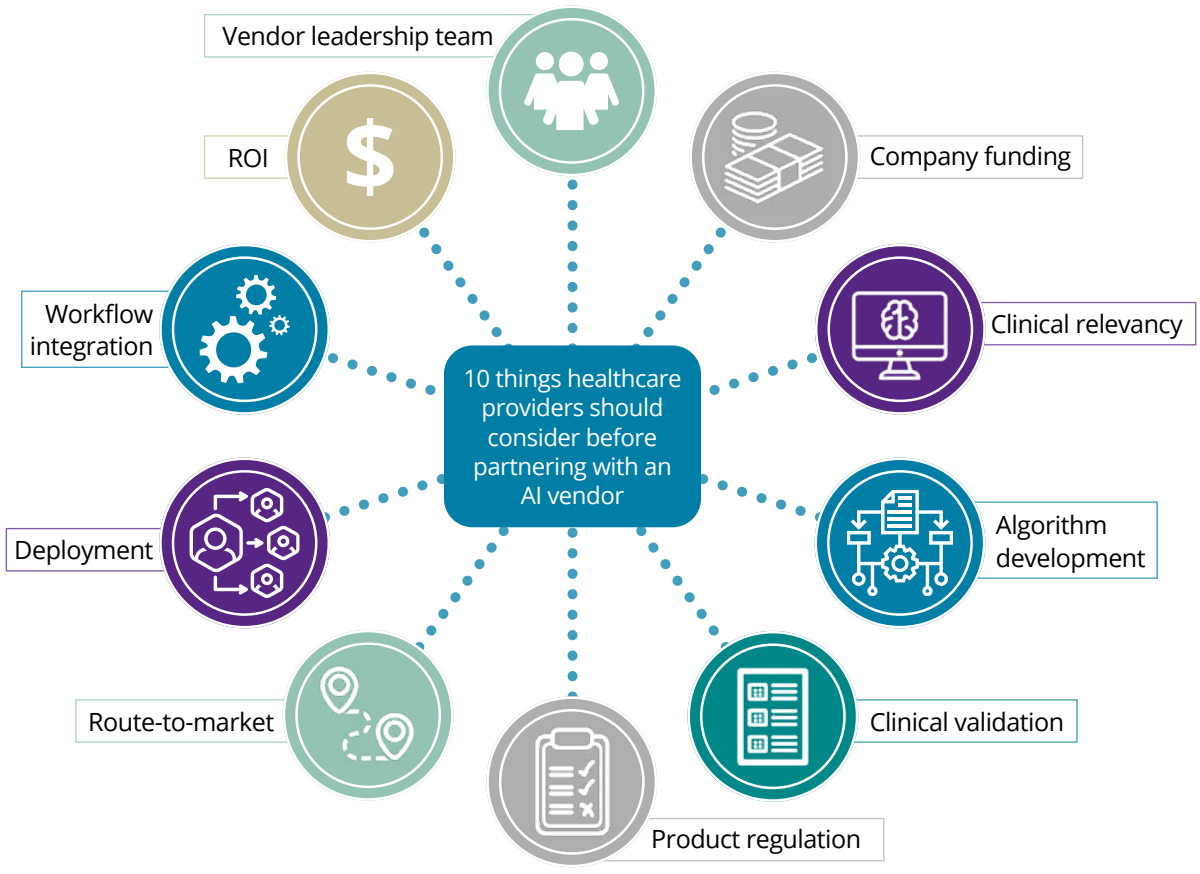
want the freedom to select their own algorithms or who are looking for a specialist or niche solution. Instead of leaving algorithm choice entirely up to providers, the custom integration approach sees the imaging IT vendor identify, select, and integrate suitable tools from AI start-ups into its core imaging platform. This custom integration approach may be preferred by some providers, as it can reduce the risks involved in selecting and purchasing AI tools, as their imaging IT vendor has essentially done the due diligence on their behalf. These differing approaches are not mutually exclusive, however, and therefore are likely to co-exist for the foreseeable future.

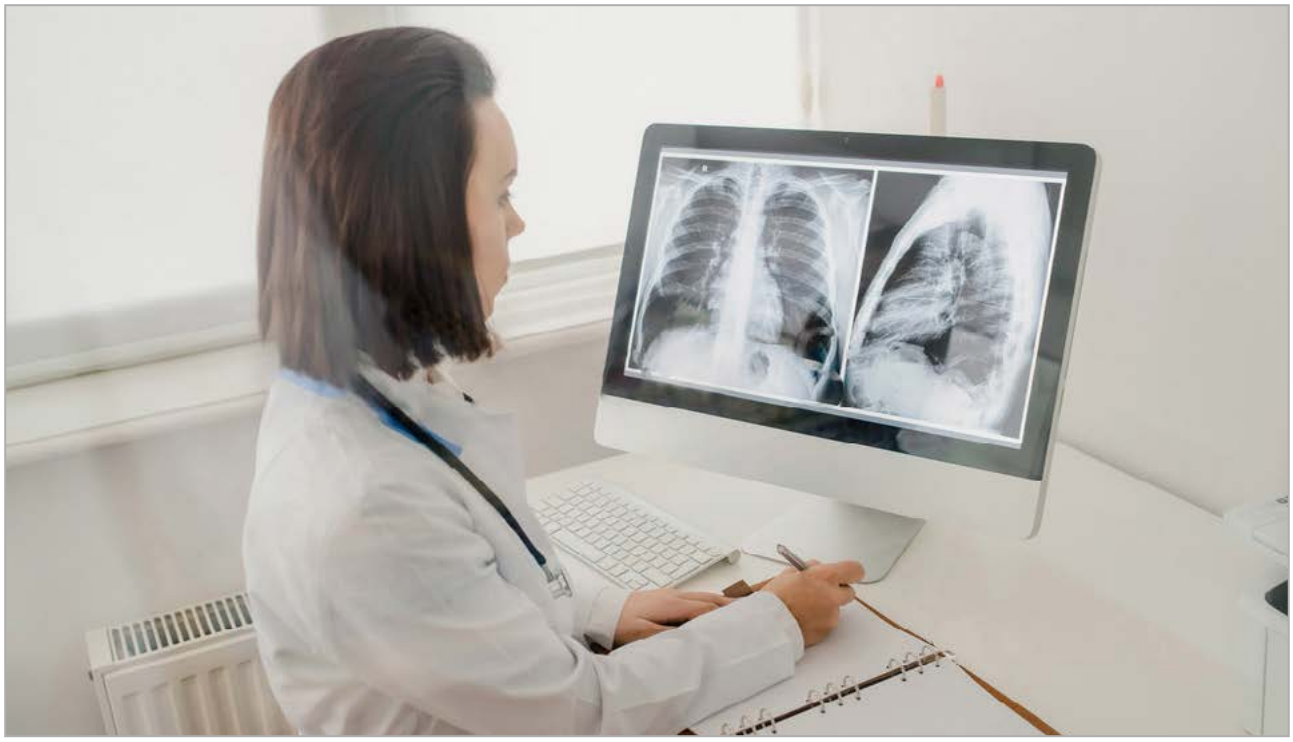
These efforts to facilitate the adoption of AI tools highlights their importance to the market as well as their potential to benefit healthcare providers and their radiologists, however, this multiplicity of approaches also highlights the nascency of the medical imaging AI market and some of the challenges that are holding it back.

Selecting AI Solutions

This plethora of AI developers all vying to stand out in the space has accelerated the development of AI. Their number, voracity and agility has allowed them to move at a pace far quicker than could be achieved by large incumbent modality and imaging IT vendors. The specialism of these companies, which are usually focused on specific clinical use-cases with narrow, single-purpose algorithms, can be advantageous in the early stages of the medical imaging AI market development, with their functional simplicity benefitting research and pilot studies. However, this specialist approach limits the utility of AI as radiologists require more clinically diverse AI tools that can support a wide range of clinical presentations and imaging findings, while the abundance of small companies also clouds the selection, purchasing, deployment and integration process.

Figure 4 10 things healthcare providers should consider before partnering with an AI vendor





The benefits of AI are well established, as such providers and their radiologists are keen to integrate the technology into their workflows, however, the options are overwhelming. With more than 200 relatively new companies offering, for the most part, narrow solutions for single tasks that have seen, aside from validation and pilot deployments, very little clinical adoption, and in many cases are very similar to other offerings from different vendors, it is difficult for providers to select which algorithm to utilise. This is not a trivial decision. To maximise the benefit of a particular algorithm, a provider will have to invest time and resource into properly integrating it into its existing imaging IT systems and clinical workflows. This investment is required for each subsequent single-purpose algorithm the provider wishes to adopt, which means that if a provider plans to leverage AI for multiple findings using single-purpose solutions with a narrow focus, it must be prepared to invest resource in integrating each. Moreover, the providers' radiologists will likely require training in how to use each selected vendor's AI solution as there is no consistency in the user interface.

A further complication for providers, and one which has been exacerbated by the economic difficulties stemming from the Coronavirus pandemic, is the need to assess the longer-term viability of the algorithm developers, often start-ups, they may wish to work with. Given the investment that must be made to properly integrate a start-up's algorithm into a provider's workflow, it would be very detrimental to commit to a start-up, only for it to cease trading, and be left with at best an unsupported algorithm, or at worst a sudden gap in clinical capability.

There are also, other more fundamental questions that must be answered before a provider can adopt a single-purpose AI algorithm. For example, is there a clinical need for the algorithm? Will use of the algorithm deliver a quantifiable return on investment or a tangible improvement in productivity? One of the potential drawbacks of many narrow AI solutions which limits their practical value in clinical settings is the minimal gain in productivity compared to the effort that is required to use them. A narrow AI solution may speed-up the detection of a specific finding, but the radiologist is still required to review the exam for other findings and hence the overall time saving may be minimal; as possibility hinted at by the distinct lack of published evidence to the contrary. Regardless of the ability of a single-purpose solution to identify a finding, if it requires a radiologist to deviate from her already efficient, well established workflow and open a separate software package or additional series in

the PACS to see the algorithm's findings, it is likely quicker for her to simply read the image manually. This is an issue that could be compounded by every additional point solution a provider adopts, with each tool adding additional complexity and disruption into a radiologist's clinical workflow.

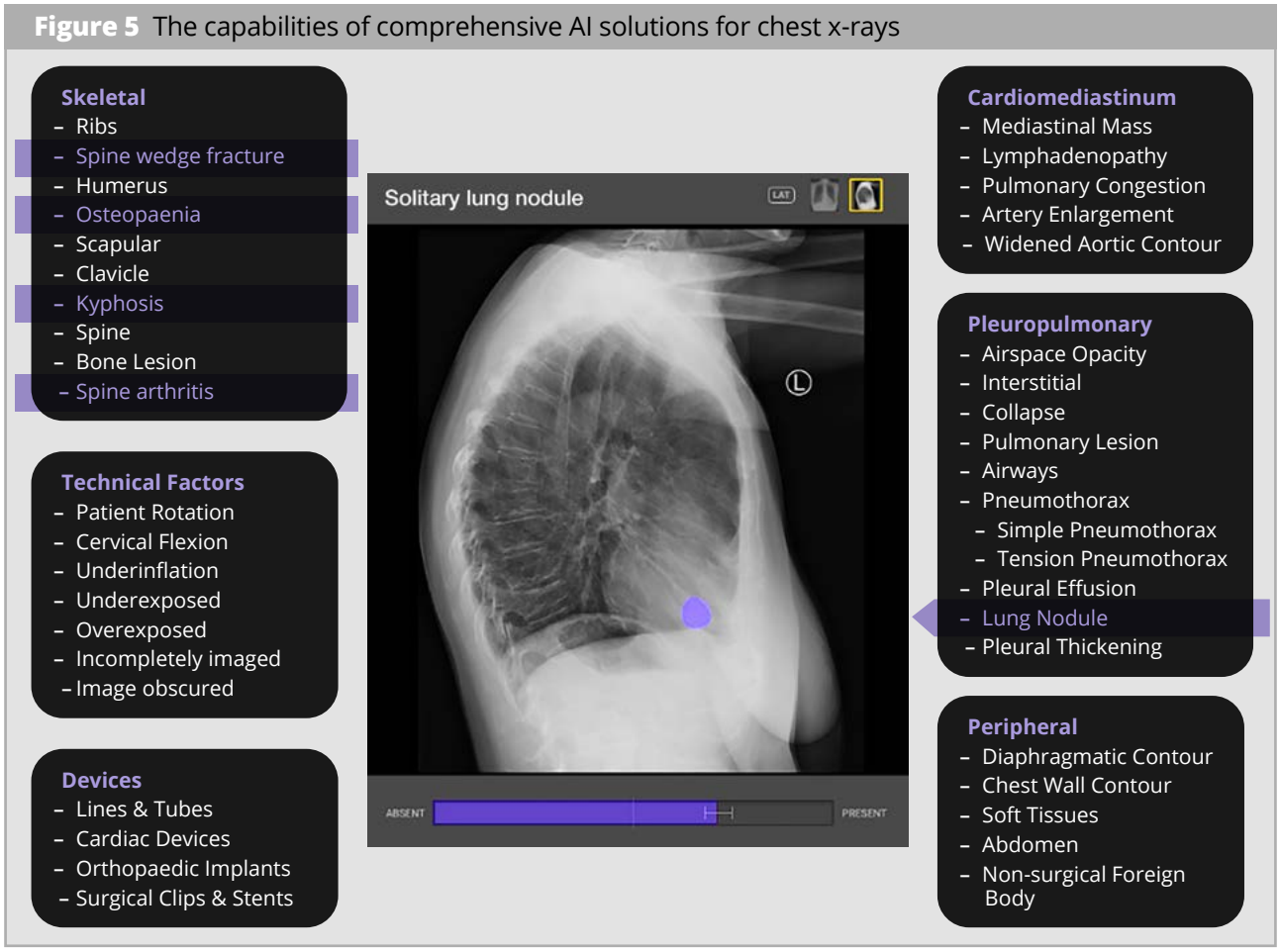
This process of painstakingly selecting an assortment of specific narrow AI algorithms is one option for providers looking to deploy AI in medical imaging, and one which some providers will utilise to access the benefits of AI. Other alternative and complementary solutions are starting to emerge, such as comprehensive AI solutions. Narrow AI algorithms assess whether a specific radiological finding is present in a scan and alert the radiologist to its presence. This may well accelerate the identification of that particular finding, but still leaves the radiologist to assess the scan and identify the presence of any other findings. In contrast, truly comprehensive AI solutions can identify the presence of most common findings for a given imaging procedure.

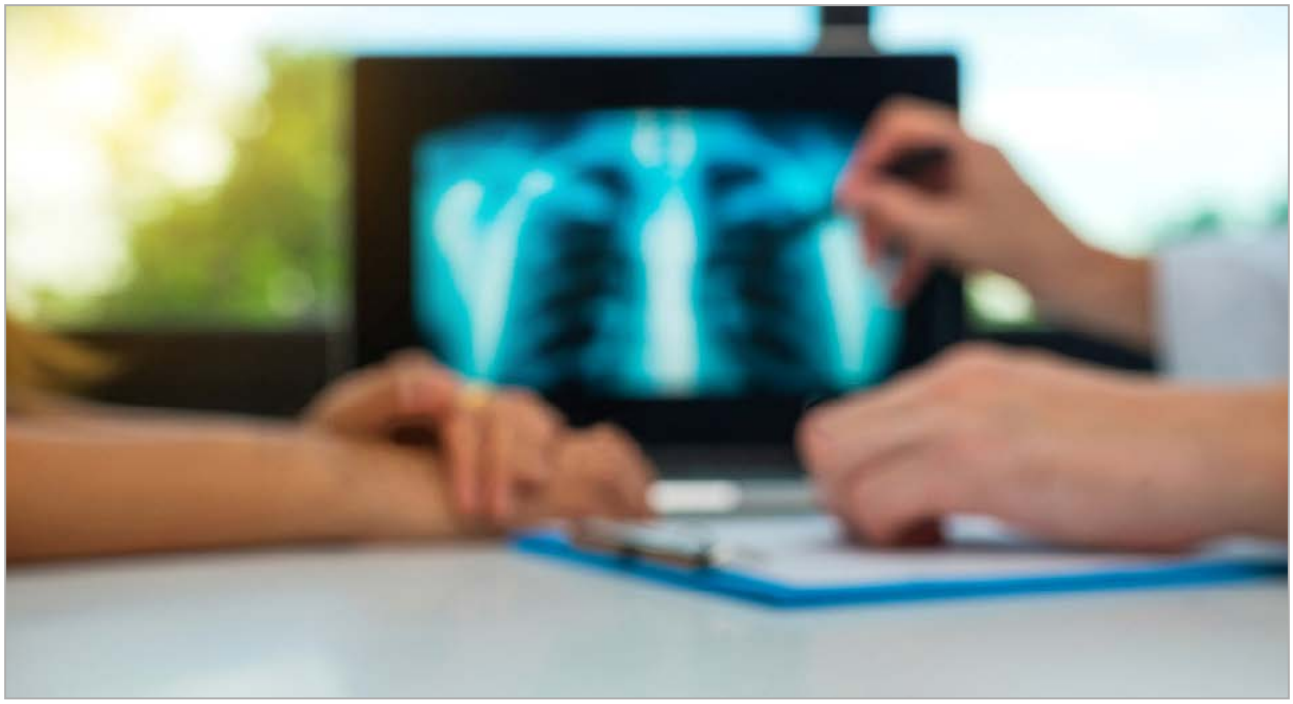
The choice of which AI vendor will therefore be made more straightforward, because unless a provider requires very specialised functionality or has very particular requirements, it will simply be able to choose a comprehensive AI solution for the most common imaging procedures. By utilising a single comprehensive solution for each category of imaging procedure, for example chest X-rays, the integration and deployment process can also be made more efficient compared to a selection of individual algorithms.

Deploying AI Solutions

This itself is among the most time consuming and human-resource intensive aspects of AI adoption. Even aside from the considerable training and change management requirements of users of new AI solutions, incorporating and supporting a single new algorithm into its PACS, without causing too much disruption and ensuring

Figure 5 The capabilities of comprehensive AI solutions for chest x-rays





that the deployment works correctly from an IT perspective is a considerable challenge. This challenge is magnified if providers require their IT departments to conduct multiple individual integrations. This piecemeal approach leads to extended timeframes for the integration of multiple algorithms, which results in hospitals and their radiologists having to wait longer before they can reap the benefits of AI solutions for multiple clinical use-cases.

From an IT perspective, the scalability of narrow AI solutions is another potential limitation, with factors like the back-end hardware required for multiple inference engines coming into play. In a system comprised of multiple algorithms from different developers, each of which may have very different AI model architectures, the system cannot be fully optimised for individual elements, slowing inference time compared to a comprehensive AI solution running on a dedicated server. Moreover, in a system that utilises multiple single-purpose algorithms, a scan will have to be delivered to each AI model, each of which requires network and compute bandwidth, both valuable commodities. As such, careful consideration must be given to minimize performance degradation of both the AI algorithms and the PACS.

Orchestrating multiple AI applications is a further obstacle. To maximise the advantages of AI, the individual algorithms would need to be used in synergy with one another, ensuring scans, and algorithms are managed correctly, and efficiently incorporated into radiologists' existing workflows. PACS vendors are beginning to incorporate these capabilities into their systems, but in order to incorporate a multitude of individual algorithms from a variety of developers, concessions must still be made. For radiologists these may include the requirement to learn and interact with multiple different user interfaces, or to look at additional imaging series, to access the results from multiple narrow algorithms. This extra complexity will not only impact the radiologist's productivity, it also makes user errors more likely.

These drawbacks may be more or less apparent depending on an individual provider's caseload. For many of the algorithms which specifically address complex, low volume cases, the hindrances that arise in the integration and orchestration of narrow AI solutions may be minimal. However, for the key imaging procedures which make up the bulk of most radiologists' workload, comprehensive AI solutions may be preferable.

Instead of having to complete separate integrations for a whole host of AI algorithms

for multiple vendors, each of which require the resource of a providers' IT team, a comprehensive AI solution will only have to be integrated once. This will become an even more significant factor in the future as AI is increasingly applied across all different imaging procedures, as the use of ever-higher numbers of narrow, single-purpose algorithms becomes ever more unfeasible. That, however, does not prevent a provider using algorithms from multiple vendors. It is likely that alongside a comprehensive solution, which could for example provide significant efficiency advantages for more routine reads, a provider may also utilise an AI marketplace, for example, to access a particular specialist tool which may be beneficial in very specific instances.

Figure 6 The limitations of narrow AI solutions

Vendor Selection and Contracting

- Multiple algorithms from multiple vendors will be required if AI is to be applied to a clinically diverse range of imaging procedures
- Time consuming and resource intensive to select multiple vendors from a large pool of relatively unknown start-ups and scale-ups
- Increased risk from working with multiple unproven vendors in terms of their longer-term viability
- Multiple vendor contracts, each with specific licensing and billing terms, creates administrative complexity and overhead

Deployment and Integration

- Multiple individual algorithm integrations can be time consuming and resource intensive for healthcare IT departments
- Back-end infrastructure cannot be fully optimised, potentially leading to slower inferencing times
- Increased risk of performance degradation and impact on PACS
- Increased deployment time, costs and long-term maintenance

In the Reading Room

- No consistency in the user experience across each selected vendors AI solution
- Radiologists will likely require training in how to use each selected vendor's AI solution
- Any productivity gains from individual algorithms are likely to be minimal

Comprehensive AI solutions also reduce the number of potential points of failure and offer more accountability. If a provider has deployed multiple algorithms or has accessed AI through a vendor platform and there is a problem with the integration or orchestration of some part of the solution, the provider could face difficulties in establishing which of its chosen algorithms is the cause, and therefore struggle to identify the vendor who is responsible for fixing the problem. By utilising a single vendor supplying a comprehensive solution, that single vendor can be held accountable, expediting the resolution of any issues. The use of a single vendor's comprehensive solution is therefore reassuring to providers working at capacity, giving them confidence that issues can be resolved quickly.

AI in the Reading Room

Comprehensive AI also offers advantages from a radiologist's perspective. When used, the radiologist will require notably less time to read a scan, as any findings will be clearly identified and presented by the AI. This will allow the radiologist's time to instead be spent on the interpretation of the findings and making a diagnosis. Furthermore, a comprehensive AI solution may enable the rule-out of imaging exams which show no abnormalities, and therefore in the future it may even be unnecessary for a radiologist to read them at all. This will help to further increase the productivity of radiologists.

Another advantage of a comprehensive solution is that it will reduce the chance of a finding being missed. Compared to narrow AI algorithms, comprehensive AI solutions operate in a way that more closely mimics a radiologist's own workflow, reading an entire scan and looking for all potential findings. This reduces the likelihood of missed diagnoses, especially for incidental or secondary findings as would be the case if a narrow AI solution detected the single finding it could and ignored other clinically relevant findings elsewhere in the scan. Comprehensive solutions solve this problem. Regardless of the reason a patient is

given a scan, it would be assessed for any possible findings, ensuring that every indicator of any pathology would still be identified and brought to the radiologist's attention.

This comprehensive assessment of scans will also help providers to better automate the triage and prioritisation of cases for improved case management. While narrow AI solutions offer some, limited triage capability, a comprehensive AI solution's ability to take into account all findings, and all of those findings in combination allow for more nuanced prioritisiation. In practice, this means a comprehensive AI solution can detect any abnormalities and more effectively prioritise exams that need immediate attention. This would be particularly beneficial in time-sensitive cases, which could see scans with indicators of acute, time-sensitive conditions prioritised for more rapid radiologist interpretation and in parallel care teams alerted, enabling shorter time to treatment for those patients. Moreover, comprehensive AI solutions can assist non-radiologist clinicians to confidently interpret certain medical images, which could advantageous in countries with a shortage of radiologists.

In addition to the clinical and efficiency benefits, comprehensive AI also has the potential to be a useful auditing tool for providers. With comprehensive AI able to identify the most common possible findings for a given imaging procedure, it offers a way to assess a radiologist's performance and ensure that the radiologist's report does not omit any clinically significant findings identified by the AI. This could prove prove beneficial in the training of radiologists, giving them constant feedback on their reads.

Figure 7 The benefits of comprehensive AI solutions

Vendor Selection and Contracting

- Fewer vendors are required so the selection process is simplified
- Fewer vendor contracts to manage
- Potentially more cost-effective than purchasing multiple narrow AI algorithms

Deployment and Integration

- Deployment and integration process is more efficient
- Optimised inference engines can deliver results faster
- Faster to scale the deployment of AI across multiple categories of imaging procedures
- Reduces the number of potential points of failure and offers more accountability

In the Reading Room

- A unified user experience for a given category of imaging procedure(s)
- Greater productivity gains from automatically analysing the entire scan and looking for all potential findings
- Reduces the likelihood of missed diagnoses, especially for incidental or secondary findings
- Can be used to separate normal from abnormal imaging exams
- A radiology auditing tool to identify areas for improvement

What the Future Holds

In its current nascent state, the medical imaging AI market is characterised by its fragmentation. It is made up of a raft of young, unproven start-ups which tend to have a relatively localised focus. For the most part, these start-ups have had a singular focus and developed tools which address specific tasks. As such, while many of these tools may have their merits in isolation, this narrow approach is a barrier to the more widespread adoption of AI and its deployment at scale in clinical practice. What's more, many of these tools were not developed to solve real-world workflow challenges or unmet clinical needs, but were instead practical applications of academic research projects, or

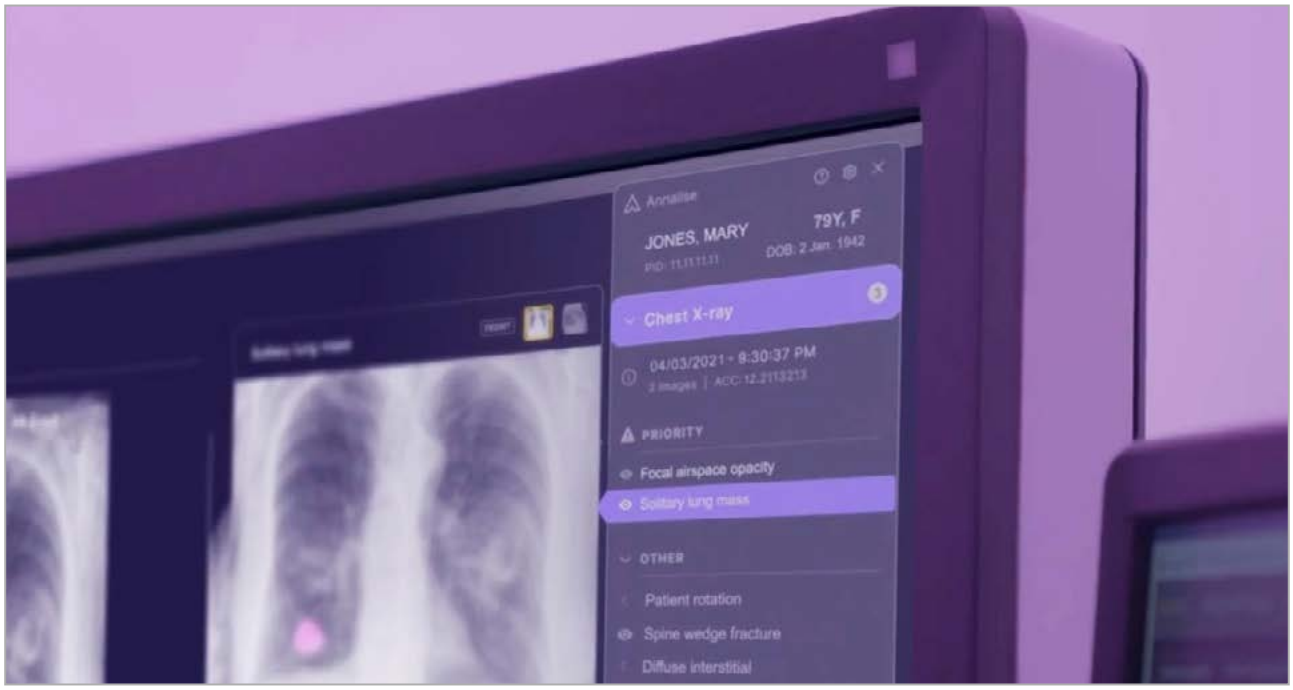
selected for development due to the availability of training data. There are surprisingly few cases where products have been developed to meet customers' actual needs.

Alongside the many technical and pragmatic challenges that come with a nascent and fragmented market is the lack of reimbursement for AI. Without reimbursement, providers will have to pay for AI tools out of their own budgets if they see significant clinical value in them, or from the budgetary savings they hope to make from improved efficiency. Another alternative for private providers is to use AI as a differentiator in the market. Teleradiology companies, for example, could tout their use of AI in a bid to beat out rivals when competing for business. At present, however, for many narrow AI products a demonstrable return on investment is missing. Not to mention the cost of buying and deploying multiple single purpose algorithms from multiple vendors. Comprehensive AI solutions offer a more-cost effective and viable solution to many of these challenges.

In the coming years, the market landscape will change. Over the mid-term market leaders will begin to emerge, as their products become better established and adopted by greater numbers of providers. These market leaders will either excel in highly valued tools for specific tasks or offer a suite of comprehensive AI solutions for a variety of imaging procedures. AI will become ever more trusted and relied on by clinicians as confidence in the technology grows.

The uptake of medical imaging AI will also be accelerated by greater support from incumbent modality and PACS vendors, which, in order to offer their customers more feature-rich solutions look set to increasingly partner with AI specialists, aiding the deployment of AI tools and more tightly integrating the results into clinical workflows. For their part, algorithm developers will also need to bridge this gap, ensuring their products seamlessly work with radiologists, regardless of the customer's preferred PACS.

Longer term, there will be further consolidation of the supplier base, as several firms establish themselves as clear market leaders. These suppliers will by now offer solutions which have moved beyond a single category of imaging procedures, to accommodate multi-organ, multi-modality solutions. AI's complexity and capability will also have evolved until it is able to offer advanced diagnostic decision support in addition to being able to identify findings, bringing further advantages in terms of both efficiency and outcomes. These improvements and advantages will make AI institutionalised and ubiquitous, becoming an integral part of a provider's imaging workflow.



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