Artificial intelligence augmentation raises questions about the future of bronchoscopy

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Shareable abstract (@ERSpublications)
This editorial discusses the article by Cold *et al.* demonstrating improvements in bronchoscopy on a model when aided by artificial intelligence (AI) software. It explores hypothetical benefits and concerns stemming from AI-enhanced bronchoscopy. https://bit.ly/3BAExJs

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Lung nodules are identified in ever greater numbers, at approximately 1.6 million nodules per year in the USA, with 95% of them estimated to be benign [1]. Early detection of malignant nodules has significant implications for the outcomes of our patients, as shown by the drastic differences in lung cancer survival between early- and late-stage diagnoses [2]. Our knowledge and techniques regarding indeterminate pulmonary nodules continue to advance, aiding us in making this distinction. In this regard, artificial intelligence (AI) tools are being introduced along every step of the "nodule pathway", and we now see the application of AI in bronchoscopy and specifically in bronchoscopy education.

In their prior work, Cold *et al.* [3] compared two groups of novices performing bronchoscopy based on different sets of instructions. The group with AI support demonstrated superior performance in terms of diagnostic completeness (DC; number of segments identified) and structured progression (SP; inspecting segments in sequential and ascending order). Additionally, the authors have also shown that there is strong concordance between SP, procedure time and DC in their prior publications [4]. In this issue of *ERJ Open Research*, Cold *et al.* [5] describe the effects of this novel AI system on a larger number of bronchoscopists at three different skill levels (novices, beginners and experts). The use of AI guidance resulted in greater DC, greater SP and more time spent on the procedure but in a more efficient manner. While AI increased the DC and SP for all groups, the effect was the greatest for novices. The results indicate that AI raised the floor for all skill levels and we see that novices with AI approximate intermediates without AI, and also that intermediates with AI approximate experts without AI when it came to procedural efficiency.

The study certainly has several strengths, namely the breadth of experience among the volunteer bronchoscopists, the numbers of volunteers and a randomised crossover design. The use of the same AI and the same bronchoscope on the same anatomic model also increases standardisation and thus the validity of the results. Certainly, however, the study is not without limitations. As the authors point out, details on the development and validation of the AI software remain unknown beyond the use of neural networks. It is uncertain if the AI software was developed on one or more than one phantom/anatomic model and then tested in the particular phantom/anatomic model for the purposes of the study. One cannot truly speculate on the reproducibility of this study if either the bronchoscope or the anatomic model is altered, even when using the same AI system. Can this AI system be used in humans, and how might it perform when evaluating pathological conditions (tumours, atelectasis, lobectomies, *etc.*) or even altered physiologic conditions (anatomic variants, *e.g.* tracheal bronchus)? Also, is the current software intended for human clinical use or for use only as part of a high-fidelity continuous feedback bronchoscopy simulator? These, of course, are questions more for the manufacturer than the authors.

So now we have a demonstrated example of AI providing real-time feedback during bronchoscopy, and this raises many further questions about what the roll-out of AI in bronchoscopy might mean for our field

TABLE 1 Hypothetical future considerations in artificial intelligence-augmented bronchoscopy

Potential benefits
Improves the performance of all skill levels
Shorter procedural times
Reduction in learning curve
Reduction in complications
Potential concerns
Affects the standard of care
Exacerbates disparities in access to care
Reduces the role of the physician
Hardware/software compatibility concerns

and our patients (table 1). Are educators and bronchoscopists ready for this incoming wave of AI-enabled bronchoscopy technology? Could we also see AI improving and assessing competency in rigid bronchoscopy, perhaps using an AI-based "coach" during simulated or live rigid bronchoscopies? A tool to assess basic competency in performing rigid bronchoscopy has already been developed by Mahmood *et al.* [6]. Now, a similar tool could be developed by incorporating real-time AI-backed feedback. If clinical practice could be augmented by AI, the bronchoscopist might be better able to know whether there are healthy or collapsed airways behind an endobronchial tumour, or even know the surrounding vasculature (*e.g.* AI + narrow band imaging + pre-operative computed tomography scan). Similarly, one could see AI-based augmentation of existing robotic bronchoscopy techniques improving navigation and accuracy. This may also improve the learning curve for the aforementioned procedures. But then again, does access to AI-enhanced training create a case of "haves" and "have nots" among pulmonology training programmes? What about those programmes that use a (future) AI-integrated real-time time "bronchoscopy coach"? This would create and exacerbate the issues of equity and access for our patients. Might these disparities then affect what is considered the prevailing standard of care? Since the AI can now log and track bronchoscopy performances could it be used to compare bronchoscopists within a programme or a city? Might we face a future of "benchmarking" bronchoscopy performance with judgements being made autonomously by AI? This would undoubtedly have legal repercussions as well. Furthermore, would this lead to an "arms race" among manufacturers? Could there be issues with interconnectedness and bundling as it pertains to hardware and software purchases? There might be scenarios where an institution might purchase bronchoscopes and biopsy instruments from one particular vendor and find itself locked into an ecosystem (think iPhone/Apple and Android/Google), because now physical hardware and AI software must remain compatible with each other. This raises other issues regarding the payments for such software – will there be a subscription model *versus* a one-time purchase? Will there be *ad hoc* updates just like for our device operating systems?

Some of these concerns are hypothetical, some will be realised, and some are still to emerge that we cannot yet fathom today. Clearly there are many leaps of robust imagination being made in this editorial as we cannot conceive what lies on the road ahead, nor where that road might go, nor who or what might make that journey. While some of this editorial is fantastical thinking, it is worth noting that Kuntz *et al.* [7] have already demonstrated autonomous needle-steering in the pulmonary parenchyma in an *in vivo* porcine model, *i.e.* bronchoscopy on autopilot.

Regarding the article, it will be interesting to see if further studies are performed in a similar manner – measuring bronchoscopy competence with and without AI support, but carried out during human bronchoscopy rather than on models. Would the benefit of using AI be maintained, lost or more pronounced? Would this or a future AI model be capable of providing "coaching" in a variety of human lungs rather than a standard model that it is trained on? Will machines be doing bronchoscopies autonomously? My humble and unsubstantiated prediction would be that we would likely be able to diagnose lung cancer without peripheral bronchoscopic biopsies before we encounter entirely autonomous bronchoscopy in routine clinical practice.

Given the increasing number of diagnostic bronchoscopy procedures expected as we find more lung nodules, these results suggest that AI may have a role to play not only in the bronchoscopy education of novice and intermediate bronchoscopists, but may even serve as a coach for expert bronchoscopists.

And for my final thoughts – if an elite athlete such as Roger Federer saw the value in having a coach, then what about coaches for expert bronchoscopists? But then again, does the coach have to be AI?

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Conflicts of interest: V. Mehta is a former *ad hoc* advisor to Qure.ai (receipt of consulting fees), reports travel support (one instance) from Noah Medical, a consultation fee from Intuitive Surgical and a consultation fee from Biodesix Inc, is an *ad hoc* scientific advisor for Oatmeal health (no receipt of any monetary or nonmonetary support), and research work for Optellum Inc. (no receipt of any monetary or nonmonetary support).

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