

# Machine learning in medical education: a survey of the experiences and opinions of medical students in Ireland

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## INTRODUCTION

Leading figures in biomedical informatics advocate education in digital health for the healthcare workforce.<sup>1 2</sup> In healthcare, artificial intelligence/machine learning (AI/ML)-enabled tools increasingly play a role by informing patient triage decisions, clinical decision support systems, and healthcare resource management<sup>3</sup> – advances that are undoubtedly set to grow.<sup>4</sup> Tens of thousands of healthcare apps are available for download by consumers, promising a range of services, from symptom tracking to diagnostic and treatment advice.

To date, surveys of medical professionals reveal divergent views about the value and impact of AI/ML on their job with many physicians sceptical about the potential scope for technological innovations on medical tasks.<sup>5–7</sup> Furthermore, surveys consistently find limited evidence of formal teaching in medical education about AI/ML. Only a few studies – conducted in Europe, the US and South Korea – have explored the formal education and familiarity of medical or healthcare students with respect to digital advances in healthcare, and much of this work consists of single site studies.<sup>8–14</sup> To better understand and engage with discussion about the benefits, limitations, and ethical dilemmas presented by these tools, today's medical students will need to become more digitally savvy. Equally, as patients make increasing use of healthcare and well-being algorithms, medical students will need to become better prepared to offer patients advice, and to have knowledge about, the robustness of these tools including when algorithms are safe to use.

In the present study, we built on this research by assessing the experiences and opinions of final year medical students throughout Ireland about their exposure to AI/ML during their entire degree programme.

## METHODS

A paper-based, cross-sectional survey was administered to final year medical students at four of Ireland's seven medical schools. Institutions were selected in each of the country's four geographical provinces. The study team devised an original survey instrument to investigate the familiarity, formal exposure to, and opinions of medical students about ML/AI in medicine. We developed the survey instrument in consultation with Irish, British, and American physicians and piloted the survey with physicians in Ireland and the UK (n=6) and final year medical students in the UK (n=5) to ensure face validity. The survey explored students' experiences and opinions about the teaching of AI/ML in their medical degree programme to date (see Section E of online supplemental appendix 1, and table 1 for survey items). Using 'yes' or 'no' responses, the survey asked whether students had heard of the term 'machine learning', were familiar with "big data analytics", and whether they had read any academic articles on AI/ML in medicine. Students were requested to estimate both how many hours their instructors or lecturers had spent, and will spend, discussing AI/ML during their degree. In addition, selecting from 'yes', 'no' or 'maybe' responses, the survey inquired whether students planned to learn about how AI/ML as it pertains to medicine. Finally, using a 6-point Likert scale, students were requested to rate their level of agreement with the statement 'Discussion about AI/ML should be part of medical training.'

The institutional review boards at University College Cork [protocol # 2018–188], National University of Ireland Galway [protocol # 19-Dec-15], Queen's University Belfast [protocol # 19.28], and University College Dublin [protocol # LS-19–89] approved the



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**Table 1** Familiarity and opinions of medical students about Artificial Intelligence/Machine learning in their medical degree

| Survey item  | Value       | 95% CI       | Total N |
|--|-------------|--------------|---------|
| Have you heard of machine learning? n (%)  | –           | –            | 242     |
| Yes  | 137 (56.6%) | 50.4 to 62.9 |         |
| No   | 105 (43.4%) | 37.1 to 49.6 |         |
| Are you familiar with big data analytics? n (%)  | –           | –            | 242     |
| Yes  | 101 (41.7%) | 35.5 to 48.0 |         |
| No   | 141 (58.3%) | 52.1 to 64.5 |         |
| Have you read any academic journal articles about artificial intelligence/ machine learning in medicine? n (%)   | –           | –            | 242     |
| Yes  | 47 (19.4%)  | 14.4 to 24.4 |         |
| No   | 195 (80.6%) | 75.6 to 85.6 |         |
| Please estimate how many hours your instructors/lecturers <i>have spent</i> discussing artificial intelligence/machine learning during your medical degree so far. median  | –           | –            | 221     |
| 0 hours  | 147 (66.5%) | –            |         |
| 30 min to 1 hour   | 38 (17.1%)  | –            |         |
| 1 hour 30 min +  | 36 (16.3%)  | –            |         |
| Please estimate how many hours your instructors/lecturers <i>will spend</i> discussing artificial intelligence/machine learning during your medical degree so far. media-n | –           | –            |         |
| 0 hours  | 133 (62.4%) |              |         |
| 30 min to 1 hour   | 19 (8.9%)   |              |         |
| 1 hour 30 min +  | 61 (28.6%)  |              |         |
| Do you plan to learn about artificial intelligence/machine learning as they pertain to medicine? n (%)   | –           | –            | 241     |
| Yes  | 99 (41.1%)  | 34.9 to 47.3 |         |
| No   | 29 (12.0%)  | 7.9 to 16.1  |         |
| Maybe  | 112 (46.5%) | 40.2 to 52.8 |         |
| Discussion about artificial intelligence/machine learning should be part of medical training.  | –           | –            | 242     |
| Strongly disagree  | 8 (3.3%)    | 1.1 to 5.6   |         |
| Moderately disagree  | 18 (7.4%)   | 4.1 to 10.7  |         |
| Somewhat disagree  | 26 (10.7%)  | 6.8 to 14.7  |         |
| Somewhat agree   | 117 (48.4%) | 42.1 to 54.6 |         |
| Moderately agree   | 45 (18.6%)  | 13.7 to 23.5 |         |
| Strongly agree   | 28 (11.6%)  | 7.5 to 15.6  |         |

study protocol at their respective sites. Between April 2019 and March 2020, the anonymous survey was distributed by lecturers after compulsory final year classes at each institution to increase responses. Participation was voluntary and all students who decided to participate provided written consent. After survey collection, responses were entered into Excel, and descriptive statistics and analysis were carried out using JASP (0.9.2) and SPSS v 27.

## RESULTS

A total of 252 of 585 (43%) of final year students across three medical schools responded. Data collection at one medical school (University College Dublin) was terminated in March 2020 because of teaching disruption due COVID-19, and survey data from this site was excluded from the analysis. Of all respondents, 157 of 251 (62.6%) were female, and 223 of 246 (90.7%) were born in 1992 or later. Among respondents, 66.5% reported zero hours of

teaching on AI/ML during their degree with 62.4% anticipating zero hours during the remainder of the degree programme, 43.4% (95% CI, 37.1% to 49.6%) had not heard of the term ‘machine learning’, and 80.6% (95% CI, 75.6% to 85.6%) had not read any academic journal articles on AI/ML. Asked about whether they intended to learn about AI/ML in medicine 41.1% (95% CI, 34.9% to 47.3%) reported ‘yes’ and 46.5% (95% CI, 40.2% to 52.8%) responded ‘maybe.’ However, 78.6% agreed that discussion about AI/ML should form part of their training. Results are reported in [table 1](#).

Descriptive data were analysed for differences according to gender and birth year. Male respondents were more likely than females to report having heard about ML (69.7% v. 48.7%),  $\chi^2(1)=10.05$ ,  $p=0.002$ . Participants who heard about ML, on average, had an earlier birth year than those who had not,  $t(234)=2.193$ ,  $p=0.029$ . Willingness to learn about AI/ML was recoded to reflect the

ordinal nature of the data (yes=1, maybe=2, and no=3) so that inferential statistics could be run. There was a trend towards younger participants being less likely to plan to learn about AI/ML,  $\rho = -.109$ ,  $p = 0.095$ . Based on the results of a Mann-Whitney U test, male respondents were more likely to plan to learn about AI/ML than female participants,  $Z = 2.25$ ,  $p = 0.025$ .

## DISCUSSION

This is the first study to explore the experiences and opinions of Irish medical students about AI/ML in their medical degree programme. Medical students reported limited awareness and education on AI/ML. Notably, around four in ten of survey respondents had not heard of the term ‘machine learning’. Around two in three respondents reported no time spent learning about AI/ML during their whole medical degree. Although a minority of students did report some formal teaching on AI/ML, it is unclear whether this was part of their compulsory medical curriculum or (for example) via elective medical courses or guest lectures. Perhaps reflecting training gaps or lack of confidence on the topic, few students reported reading any academic articles on AI/ML in medicine. Relatedly, students were divided about their plans to fill educational gaps, with almost half of students reporting some uncertainty about whether they would undertake additional learning on these topics. Contrary to our expectations, younger participants were less likely to have heard of ML; however, the majority of participants were typically young adults: 91% had a birth year between 1992–1999. Conceivably, with greater variance in ages of participants we might have observed different findings. Finally, while the majority of students reported a lack of formal instruction on AI/ML in medicine, considerably fewer students seemed to approve of the status quo. In common with other surveys,<sup>8,9,12–14</sup> the majority of medical students considered learning about AI/ML should form part of their formal medical degree.

To help address education deficits, we suggest medical schools consider developing short, cross-disciplinary courses in digital health, including an understanding of augmented intelligence, to empower students to keep abreast of technological advances. Indeed, the need for further education on these topics may also apply to allied health professional training including nursing, pharmacy, clinical psychology, and physiotherapy. Because technology changes rapidly, we recommend that training and education encompass critical thinking skills so that students are well equipped to appraise new technologies. For example, courses in evidence-based medicine might incorporate discussion about evaluation of clinical decision support systems, the potential for algorithmic biases in data sets, and challenges associated with the explainability of AI/ML decisions. Medical ethics courses might usefully incorporate topics related to patient privacy with the use of digital devices and apps, and the potential for AI/ML-tools to mitigate or exacerbate digital divides in

healthcare. Finally, we caution that without solid curricular advances, medical students and health professionals may rely too heavily on hype or inflated media reportage to inform their views, leading to negative consequences for healthcare. For example, surveys in Canada and the UK suggest that, under the misguided view that radiology will be imminently replaced as a field by AI/ML, students are more likely to rule out this specialty as a career choice.<sup>12,15</sup>

This study has some strengths and limitations. A strength was soliciting the views of students from institutions in geographically distinctive regions of the country. However, the moderate response rate (43%) raises questions about representativeness. Response biases could also have influenced our findings depending on whether students most enthusiastic or those inclined to view AI/ML negatively answered the survey. While our aim was to gauge the general awareness of medical students about these topics, some survey items, such as ‘familiarity with big data analytics’ might be challenged as vague and open to interpretation. We recommend that qualitative research methods might provide more nuanced findings on students’ opinions and awareness about AI/ML in medicine. In addition, we suggest future studies might usefully explore the opinions and familiarity of medical faculty about AI/ML in medical education, and/or evaluate medical curricula course content to assess where, if at all, students acquire learning on these topics. Finally, the survey was administered prior to the COVID-19 pandemic which has overseen considerable developments and attention given to the role of AI/ML-enabled tools including in digital epidemiology and public health. Conceivably, as a result, had the survey been undertaken today we might have found increased awareness or familiarity about these topics among medical students. However, we emphasise it remains to be seen whether this heightened attention translates into tangible curricular developments. Furthermore, no surveyed medical school has since modified their curriculum to include education about AI/ML.

We close by noting, in recent years Ireland has gained recognition as a global technology hub with the fastest growing tech workforce in Europe.<sup>16</sup> Despite these advances, we cannot help but observe the risk of digital education in healthcare lagging behind. Improvements in digital education will help prepare tomorrow’s doctors to lead policy and practice advances on the role of AI/ML-enabled tools in the health professions and in patientcare.

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**MACHINE LEARNING AND MEDICINE:  
OPINIONS OF STUDENTS IN IRISH MEDICAL SCHOOLS**

**Information Sheet and Consent Form**

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, so as to enable you to make an informed choice.

The purpose of this study is to investigate the opinions of final year medical students in Ireland about technology and the future of medicine. We do not expect any knowledge of technologies: instead we are interested in your views as students'. Should you choose to participate, you will be asked some non-identifying demographic information, followed by questions with multiple choice answers asking you to express your level of agreement with various statements about how medicine might be impacted by technology. We are also interested in any comments you might have, should you feel able to provide them. The survey will take around 10-15 minutes to complete.

Your responses will help us to better understand the opinions of future medical professions on artificial intelligence, which in turn may help to inform medical curricula. While there are no direct benefits to you, participating in this survey may help to stimulate you to think about the role of technology in healthcare.

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so you can refuse to answer specific questions, or decide to withdraw from the study. We will not collect any personal or sensitive information therefore the survey will be fully anonymous. The survey is not a test, and your decision to participate will not affect your grades. Ticking the box below will indicate consent to participate.

You maintain the right to withdraw from the study at any stage up to the point of data submission. At this point your data will be collated with that of other participants and can no longer be retracted.

The anonymous data will be stored securely for up to ten years on the NUIG Server in secured form. The information you provide may contribute to research publications and/or conference presentations which may be publicly available. However, your contributions will be fully anonymous.

We do not anticipate any negative outcomes from participating in this study.

This study has obtained ethical approval from the Research Ethics Committee at NUIG.

If you have any queries about this research, you can contact Dr Muiris Houston at [muiris.houston@gmail.com](mailto:muiris.houston@gmail.com)

If you agree to take part in this study, please complete the consent question below.

### Consent Form

Do you consent to participate in this study?

Yes

No



**MACHINE LEARNING AND MEDICINE:  
OPINIONS OF STUDENTS IN IRISH MEDICAL SCHOOLS**

**Dear Student,**

**Researchers at the School of Medicine, NUIG invite you to take part in a survey. We are inviting you, as medical students to give your opinions about technology and the future of medicine. This research will help to inform medical educationalists and policy-makers.**

The survey should take around 10 (and no more than 15) minutes to complete. We will not collect any identifying information from you, and your responses will be fully anonymous. Your response will be collated with those of other respondents in aggregated, anonymous form. ***This survey is not a test; we are interested in your opinions as medical students.*** We refer you to the Information and Consent Sheet for more information.

If you decide to participate, we appreciate your time and contribution to our research.

Thank you.

Dr Muiris Houston, NUIG

Email contact: [muiris.houston@gmail.com](mailto:muiris.houston@gmail.com)

**SECTION A**

In this section we will ask demographic questions.

**A1. Gender. Please select box.**

- Male  1
- Female  2
- Not listed above (please specify)  3
- Prefer not to answer  4

**A2. Year of birth. Please enter year.**

**A3. Current year of your medical school education. Please select box.**

- 1<sup>st</sup>  1
- 2<sup>nd</sup>  2
- 3<sup>rd</sup>  3
- 4<sup>th</sup>  4
- 5<sup>th</sup>  5

**A4. (i) Are you a graduate-entry student ('GEM')? Please select box.**

- No  1
- Yes  2

**(i) If you answered 'Yes' what was your undergraduate degree subject(s)? Please enter.**

**A5. What general area of medical specialty do you plan to enter? Please select one box only.**

- General practice  1
- Internal medicine (any sub-specialty)  2
- Paediatrics  3
- Elderly care/ Geriatrics  4
- General Surgery  5
- Other surgery specialty  6
- Anesthetics  7
- Radiology  8
- Pathology (any sub-specialty)  9
- Other (please specify)  10

**A6. \*\*[OPTIONAL] Please enter your nationality.**

**A7. \*\*[OPTIONAL] What is your race/ethnicity? Please select.**

- Asian  1
- Black  2
- White  3
- Mixed  4
- Other - Please specify  5

## **SECTION B**

**The questions in this section are on your opinions about the impact of machine learning/artificial intelligence on the future of primary care.**

**We do not assume you have any knowledge about machine learning or artificial intelligence in medicine.**

**Some people believe that machine learning/artificial intelligence will lead to significant changes in medical practice and that machines will one day replace the work of physicians; others deny that new technologies will ever have the capacity to replace this work.**

**While there is much debate about the impact of machine learning/artificial intelligence on medicine, we are interested in your opinions.**

**In this section we invite you to give your views about whether future technology will be able to perform various medical tasks as well as or better than the average GP.**

**In the questions below, we are interested in whether you believe technology will be able to FULLY REPLACE – NOT MERELY AID – GPs in performing these tasks.**

**The questions begin on the next page.**

**B1. In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...**

**B1(i) Analyse patient information to reach diagnoses.**

|               |                                       |   |                           |
|---------------|---------------------------------------|---|---------------------------|
| Very unlikely | <input type="checkbox"/> <sub>1</sub> | } | Go to <b>B2</b>           |
| Unlikely      | <input type="checkbox"/> <sub>2</sub> |   |                           |
| Likely        | <input type="checkbox"/> <sub>3</sub> | } | First go to <b>B1(ii)</b> |
| Very likely   | <input type="checkbox"/> <sub>4</sub> |   |                           |

**B1(ii) If you answered Likely or Very likely:**

**When, in your estimation, will future technology have the capacity to fully replace the average GP in performing this task?**

|                             |                                       |
|-----------------------------|---------------------------------------|
| 0-4 years from now          | <input type="checkbox"/> <sub>1</sub> |
| 5 to 10 years from now      | <input type="checkbox"/> <sub>2</sub> |
| 11 to 25 years from now     | <input type="checkbox"/> <sub>3</sub> |
| 26-50 years from now        | <input type="checkbox"/> <sub>4</sub> |
| More than 50 years from now | <input type="checkbox"/> <sub>5</sub> |

**B2.** In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...

**B2(i)** Analyse patient information to predict the likely course of the patient's illness.

|               |                                       |   |                           |
|---------------|---------------------------------------|---|---------------------------|
| Very unlikely | <input type="checkbox"/> <sub>1</sub> | } | Go to <b>B3</b>           |
| Unlikely      | <input type="checkbox"/> <sub>2</sub> |   |                           |
| Likely        | <input type="checkbox"/> <sub>3</sub> | } | First go to <b>B2(ii)</b> |
| Very likely   | <input type="checkbox"/> <sub>4</sub> |   |                           |

**B2(ii)** *If you answered Somewhat likely, Likely or Very likely:*

**When, in your estimation, will future technology have the capacity to fully replace the average GP in performing this task?**

|                             |                                       |
|-----------------------------|---------------------------------------|
| 0-4 years from now          | <input type="checkbox"/> <sub>1</sub> |
| 5 to 10 years from now      | <input type="checkbox"/> <sub>2</sub> |
| 11 to 25 years from now     | <input type="checkbox"/> <sub>3</sub> |
| 26-50 years from now        | <input type="checkbox"/> <sub>4</sub> |
| More than 50 years from now | <input type="checkbox"/> <sub>5</sub> |

**B3. In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...**

**B3(i) Evaluate when to refer patients to other health professionals.**

|               |                                       |   |                           |
|---------------|---------------------------------------|---|---------------------------|
| Very unlikely | <input type="checkbox"/> <sub>1</sub> | } | Go to <b>B4</b>           |
| Unlikely      | <input type="checkbox"/> <sub>2</sub> |   |                           |
| Likely        | <input type="checkbox"/> <sub>3</sub> | } | First go to <b>B3(ii)</b> |
| Very likely   | <input type="checkbox"/> <sub>4</sub> |   |                           |

**B3(ii) If you answered *Somewhat likely, Likely or Very likely*:**

**When, in your estimation, will future technology have the capacity to replace the average GP in performing this task?**

|                             |                                       |
|-----------------------------|---------------------------------------|
| 0-4 years from now          | <input type="checkbox"/> <sub>1</sub> |
| 5 to 10 years from now      | <input type="checkbox"/> <sub>2</sub> |
| 11 to 25 years from now     | <input type="checkbox"/> <sub>3</sub> |
| 26-50 years from now        | <input type="checkbox"/> <sub>4</sub> |
| More than 50 years from now | <input type="checkbox"/> <sub>5</sub> |

**B4. In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...**

**B4(i) Formulate personalised treatment plans for patients.**

|               |                          |   |   |                           |
|---------------|--------------------------|---|---|---------------------------|
| Very unlikely | <input type="checkbox"/> | 1 | } | Go to <b>B5</b>           |
| Unlikely      | <input type="checkbox"/> | 2 |   |                           |
| Likely        | <input type="checkbox"/> | 3 | } | First go to <b>B4(ii)</b> |
| Very likely   | <input type="checkbox"/> | 4 |   |                           |

**B4(ii) If you answered *Somewhat likely, Likely or Very likely*:**

**When, in your estimation, will future technology have the capacity to replace the average GP in performing this task?**

|                             |                          |   |
|-----------------------------|--------------------------|---|
| 0-4 years from now          | <input type="checkbox"/> | 1 |
| 5 to 10 years from now      | <input type="checkbox"/> | 2 |
| 11 to 25 years from now     | <input type="checkbox"/> | 3 |
| 26-50 years from now        | <input type="checkbox"/> | 4 |
| More than 50 years from now | <input type="checkbox"/> | 5 |

**B5** In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...

(i) **Provide empathetic care to patients.**

|               |                          |   |   |                           |
|---------------|--------------------------|---|---|---------------------------|
| Very unlikely | <input type="checkbox"/> | 1 | } | Go to <b>B6</b>           |
| Unlikely      | <input type="checkbox"/> | 2 |   |                           |
| Likely        | <input type="checkbox"/> | 3 | } | First go to <b>B5(ii)</b> |
| Very likely   | <input type="checkbox"/> | 4 |   |                           |

**B5(ii)** *If answered Somewhat likely, Likely or Very likely:*

**When, in your estimation, will future technology have the capacity to fully replace the average GP in performing this task?**

|                             |                          |   |
|-----------------------------|--------------------------|---|
| 0-4 years from now          | <input type="checkbox"/> | 1 |
| 5 to 10 years from now      | <input type="checkbox"/> | 2 |
| 11 to 25 years from now     | <input type="checkbox"/> | 3 |
| 26-50 years from now        | <input type="checkbox"/> | 4 |
| More than 50 years from now | <input type="checkbox"/> | 5 |

**B6. In your opinion, what is the likelihood that future technology will be able to fully replace human doctors to perform the following task as well as or better than the average GP...**

**(i) Provide documentation (e.g., update medical records) about patients.**

|               |                          |   |   |                           |
|---------------|--------------------------|---|---|---------------------------|
| Very unlikely | <input type="checkbox"/> | 1 | } | Go to <b>B7</b>           |
| Unlikely      | <input type="checkbox"/> | 2 |   |                           |
| Likely        | <input type="checkbox"/> | 3 | } | First go to <b>B6(ii)</b> |
| Very likely   | <input type="checkbox"/> | 4 |   |                           |

**B6(ii) If answered Somewhat likely, Likely or Very likely:**

**When, in your estimation, will future technology have the capacity to fully replace the average GP in performing this task?**

|                             |                          |   |
|-----------------------------|--------------------------|---|
| 0-4 years from now          | <input type="checkbox"/> | 1 |
| 5 to 10 years from now      | <input type="checkbox"/> | 2 |
| 11 to 25 years from now     | <input type="checkbox"/> | 3 |
| 26-50 years from now        | <input type="checkbox"/> | 4 |
| More than 50 years from now | <input type="checkbox"/> | 5 |

**B7. In 25 years, of the following options, in your opinion what is the likely impact of artificial intelligence/machine learning on the work of GPs.**

No influence (GPs' jobs will remain unchanged)

1



Go to **Section C**

Minimal influence (GPs' jobs will change slightly)

2

Moderate influence (GPs' jobs will change substantially)

3

Extreme influence (GPs' jobs become obsolete)

4



First go to **B8**

**B8. Please briefly describe the way(s) you believe artificial intelligence/machine learning will change GPs' jobs in the next 25 years.**

**Thank you for completing Section B.**

**Please turn over for Section C.**

**SECTION C**

**In this section we ask you to provide your level of agreement/disagreement with different statements.**

**C1. 25 years from now, technology (e.g., smartphone apps) will be used to decide when patients need to see a GP.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**C2. 25 years from now, GPs will routinely work in partnership with artificial intelligence/machine learning to diagnose patients.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**C3. 25 years from now, GPs will routinely work in partnership with artificial intelligence/machine learning to determine the likely course of a patient's illness.**

|                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**C4. 25 years from now, GPs will routinely work in partnership with artificial intelligence/machine learning to devise patient treatment plans.**

|                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**C5. 25 years from now, remote monitoring of patients' vital signs will be more common than in-person check-ups of vital signs with GPs.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**C6. 25 years from now, patients' will have greater access to their own medical records than they do today.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**Thank you for completing Section C.**

**Please turn over for Section D.**

**SECTION D**

**This section asks you questions about the potential benefits and harms of artificial intelligence/machine learning in medical care. Again, we ask you to provide your level of agreement/disagreement with different statements.**

**D1. 25 years from now, the implementation of innovations in artificial intelligence/machine learning will reduce rates of diagnostic errors in medicine.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**D2. 25 years from now, the implementation of innovations in artificial intelligence/machine learning will increase patient access to medical care.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**D3. 25 years from now, the implementation of innovations in artificial intelligence/machine learning will reduce healthcare costs.**

- Strongly disagree  1
- Moderately disagree  2
- Somewhat disagree  3
- Somewhat agree  4
- Moderately agree  5
- Strongly agree  6

**D4. If offered the choice patients would prefer home monitoring of vital signs compared to visiting their GP.**

- Strongly disagree  1
- Moderately disagree  2
- Somewhat disagree  3
- Somewhat agree  4
- Moderately agree  5
- Strongly agree  6

**D5. Patients will always prefer receiving important medical information via face-to-face consultations with GPs rather than via their devices.**

- |                     |                          |   |
|---------------------|--------------------------|---|
| Strongly disagree   | <input type="checkbox"/> | 1 |
| Moderately disagree | <input type="checkbox"/> | 2 |
| Somewhat disagree   | <input type="checkbox"/> | 3 |
| Somewhat agree      | <input type="checkbox"/> | 4 |
| Moderately agree    | <input type="checkbox"/> | 5 |
| Strongly agree      | <input type="checkbox"/> | 6 |

**D6. Please provide any brief comments you may have about the potential benefits of artificial intelligence/machine learning in medicine.**

**D7. Please provide any brief comments you may have about the potential harms of artificial intelligence/machine learning in medicine.**

## SECTION E

The questions in this section ask about your familiarity with artificial intelligence/machine learning.

**E1. Have you heard of machine learning?**

No  <sub>1</sub>  
Yes  <sub>2</sub>

**E2. Are you familiar with big data analytics?**

No  <sub>1</sub>  
Yes  <sub>2</sub>

**E3. Have you read any academic journal articles about artificial intelligence/machine learning in medicine?**

No  <sub>1</sub>  
Yes  <sub>2</sub>

**E4. Please estimate how many hours your instructors/lecturers have spent discussing artificial intelligence/machine learning during your medical degree so far.**

**E5. Please estimate how many hours your instructors/lecturers will spend discussing artificial intelligence/machine learning during the course of obtaining your medical degree.**

**E6. Do you plan to learn about artificial intelligence/machine learning as they pertain to medicine?**

No  1

Yes  2

Maybe  3

**E7. Discussion about artificial intelligence/machine learning should be part of medical training.**

Strongly disagree  1

Moderately disagree  2

Somewhat disagree  3

Somewhat agree  4

Moderately agree  5

Strongly agree  6

**Thank you for completing Section E.**

**Please turn to the final question in Section F.**

**SECTION F**

The question in this section is about your perceptions of the GP workforce.

**F1. The number of primary care physicians worldwide is...**

- |                                  |                          |   |
|----------------------------------|--------------------------|---|
| Much less than the demand        | <input type="checkbox"/> | 1 |
| Somewhat less than the demand    | <input type="checkbox"/> | 2 |
| About equal to the demand        | <input type="checkbox"/> | 3 |
| Somewhat greater than the demand | <input type="checkbox"/> | 4 |
| Much greater than the demand     | <input type="checkbox"/> | 5 |

**THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY!**  
**PLEASE RETURN YOUR COMPLETED SURVEY**