# Radiologist's views on anatomical knowledge amongst junior doctors and the teaching of anatomy in medical curricula

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## ARTICLE INFO

## ABSTRACT

Reduced teaching resources, increasing student numbers and congested medical curricula have led to reports of inadequate anatomical knowledge among newly qualified doctors, placing scrutiny on pre-clinical education. We wished to gauge the opinions of practicing radiologists on undergraduate anatomy education. Members of the Irish Faculty of Radiologists were invited to complete a questionnaire based on anatomy teaching practices, its relevance and the standards of anatomical knowledge at graduation. Out of 67 respondents, 69% were of senior grade, with the majority working in diagnostic radiology. Respondents universally agreed that anatomy is central to radiology; however, decade of graduation significantly influenced radiologist's level of satisfaction with their anatomical knowledge at the start of their training. Fifty percent believed that the cadaver should remain the cornerstone of anatomy education. The vast majority of radiologists agreed that radiology and anatomy should be taught in tandem during pre-clinical training to better prepare students for clinical practice. Practicing radiologists believed they were best positioned to deliver radiology-based anatomy teaching. CT and MRI respectively were proposed as the preferred imaging modalities for teaching anatomy, although free comments showed varied opinion on how radiology and cadaveric anatomy should be integrated. Radiologists were also concerned with the anatomical knowledge of the junior doctor. This study may add to the debate concerning the vertical integration of anatomy in medical education and may help inform the delivery of radiology in the anatomy curriculum.

## 1. Introduction

The increasing use of digitized resources and other non-invasive / invasive medical techniques such as ultrasound and endoscopy are promoting the vertical integration of anatomy education (Jacobson et al., 2009; Bhogal et al., 2012; Brown et al., 2012; Arya et al., 2013; Webb and Choi, 2014; Colucci et al., 2015; Kumar et al., 2016; Patel et al., 2017). In addition, academics, students and physicians have stated that while cadaveric dissection / prosection is at the core of anatomy education, surgical and radiology based teaching should form a greater component of syllabus requirements (Drake et al., 2002; Zafar, 2009; Nyhsen et al., 2011; Arráez-Aybar et al., 2014; Davis et al., 2014; Marom and Tarrasch, 2015; Barry et al., 2016; Sheikh et al., 2016). Radiology forms a component of the curriculum

in the majority of United States (80%), Canadian (92%), Australian, United Kingdom, Ireland and New Zealand (100%) based medical schools (Mitchell and Williams, 2002; Craig et al., 2010; Jack and Burbridge, 2012). As such, radiology is a growing component of many undergraduate curricula and is welcomed as an alternative teaching tool by academics and as a necessary training platform by clinicians (Squire and Novelline, 1985; Morrissey and Heilbrun, 2017; Davis et al., 2018). However, despite best practice guideline recommendations from medical organizations such as the Association of American Medical Colleges (AAMC, 1998), the General Medical Council (GMC, 2015), the Royal College of Physicians and Surgeons of Canada (Frank, 2005), the role of radiology in medical curricula is not consensus-led and many anatomy departments do not significantly engage their anatomy syllabus with radiology teaching (Samuel and Shaffer, 2000; Mitchell and Williams, 2002; Ganske et al., 2006; Heptonstall et al., 2016). The changing landscape of anatomy education (Estai and Bunt, 2016) has already led to opinions on the disciplines pedagogy being sought from health professionals to ideally vertically align learning outcomes (Straus

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et al., 2014; Sheikh et al., 2016). The aim of this research is to evaluate radiologist's perceptions towards current anatomy teaching practices. We assessed their opinions of their own anatomical knowledge at graduation and that of modern medical graduates. We also evaluated their opinions about how best to deliver anatomy teaching to preclinical medical students, whether radiology should play a role in anatomy teaching, and which type of radiology is of most teaching benefit. These data provide key insights into the roles and significance of radiology in anatomy education from the perspective of radiologists and are discussed in the context of associated literature.

## 2. Methods

In January 2017, the secretary for the Faculty of Radiologists, Royal College of Surgeons in Ireland, circulated a link to an online anonymized survey to all radiologists registered with the Faculty, which was approximately 320 practicing radiologists. Survey answers were collected in January and February of 2017. The Faculty of Radiologists is the professional and academic body for radiologists, providing training for diagnostic radiologists and radiation oncologists in Ireland. Faculty members work in hospitals and out-patient care and most interact with medical students. The first four questions assessed demographics including gender, region of graduation, year of graduation and current professional level. The next ten questions assessed radiologist's views on the importance of anatomical knowledge, personal and current levels of anatomy amongst graduates, the integration of radiology in anatomy education, the role of the cadaver in anatomy education, and finally anatomy teaching tools including radiology.

Each question offered respondents the opportunity to provide free comments. All survey data from respondents was downloaded from Survey Monkey® collated and entered into Excel, version 14.0 (Microsoft Corp., Redmond, WA) or exported to the Statistical Package for Social Scientists (SPSS), version 23 (IBM Corp., Armonk, NY) for statistical analyses. Descriptive statistics showing the mean Likert score ± standard deviation (SD) for all the questions are shown in Table 2. Where participants were asked to rate their level of agreement with individual statements, they were asked to select one answer on a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree. Likert scale data were analyzed using non-parametric Kruskal–Wallis testing with pairwise comparisons using the Dunn's procedure with a Bonferroni correction for multiple comparisons, or a Mann–Whitney test as appropriate to carry out an *a priori* analysis on the influence of 'decade of graduation' and 'professional grade' on participants' views on anatomy and radiology teaching. For questions assessing different aspects of the same construct a Cronbach's alpha was calculated to assess reliability. Data were considered to be statistically significant at $p < 0.05$. Ethical approval to conduct this research was approved by the research ethics committee at Trinity College Dublin.

## 3. Results

### 3.1. Radiologist demographics

Sixty-seven participants completed the survey for a response rate of 20.9%. The respondents consisted of 20 females ($n = 20$; 29.9%) and 47 males ($n = 47$; 70.1%) that had graduated during the last five decades (Table 1). All graduated between 1971 and 2017, primarily from universities in the Republic of Ireland. Respondents were categorized into junior grades ($n = 21$; 31.3%) and senior radiologist grades as consultant physicians (this is equivalent to an attending physician in the United States) ($n = 46$; 68.7%) (Table 1).

**Table 1**
Demographics of the survey population.

| Characteristics | $n$ (%) |
|---|---|
| Gender | |
| Female | 20 (29.9) |
| Male | 47 (70.1) |
| Total | 67 (100) |
| Region of graduation | |
| Ireland | 62 (92.5) |
| Other | 5 (7.5) |
| Year of graduation | |
| 1971–1980 | 7 (10.4) |
| 1981–1990 | 17 (25.4) |
| 1991–2000 | 13 (19.4) |
| 2001–2010 | 17 (25.4) |
| 2011–2017 | 13 (19.4) |
| Professional grade | |
| Junior radiologist. intern and registrar | 21 (31.3) |
| Senior radiologist. consultant and senior fellow | 46 (68.7) |

**Table 2**
Decade of graduation and professional grade.

| Year of graduation | Percentage respondents | Professional grade |
|---|---|---|
| 1971– 1980 | 10.4 % (n = 7) | All consultant |
| 1981–1990 | 25.4 % (n = 17) | All consultant |
| 1991–2000 | 19.4 % (n = 13) | All consultant |
| 2001–2010 | 25.4 % (n = 17) | 58.8 % (n = 10) registrar |
| | | 5.9 % (n = 1) senior fellow |
| | | 35.3 % (n = 6) consultant |
| 2011–2017 | 19.4 % (n = 13) | 92.3 % (n = 12) registrar |
| | | 7.7 % (n = 1) consultant |

All respondents graduating between 1971 and 2000 were of consultant grade (Table 2). Those graduating from 2001 to 2017 classified themselves as registrar, consultant or senior fellow grades (Table 2).

### 3.2. The importance of anatomical knowledge in radiology

To establish a baseline, participants were first asked whether they believed anatomical knowledge was important to the field of radiology. There was near universal agreement that it was important (mean Likert score = 4.9 ± 0.50), with no significant differences found between groups from different decades of graduation (Q1; Table 3) ($X^2(4) = 2.569$, $p = 0.632$) (graph not shown).

### 3.3. Radiologists views on anatomical knowledge amongst junior doctors

Having established the baseline that all participants viewed anatomy as important, we next sought to determine whether respondent's opinions on anatomy as it relates to radiology were influenced by year of graduation. To do this, we determined if there were differences in the mean ranks of Likert scores between the five groups of participants with different decades of graduation: '1971–1980' ($n = 7$), '1981–1990' ($n = 17$), '1991–2000' ($n = 13$), '2001–2010' ($n = 17$) and '2011–2017' ($n = 13$). The mean ranks of Likert scores were significantly different between the groups when asked whether their level of anatomy was sufficient to begin training as a radiologist upon leaving medical school (Q2; Table 3) ($X^2(4) = 13.607$, $p = 0.009$). Values are mean ranks unless otherwise stated. This *post-hoc* analysis revealed significant differences between the '2011–2017' (mean rank = 18.31) and '2001–2010' groups (mean rank = 38.5) ($p = 0.037$) and the '1991–2000' group (mean rank = 43.58) ($p = 0.007$) (Fig. 1A). We also grouped the survey population into two categories based on whether participants were working at senior grade or more junior grades. The mean ranks of Likert scores were not significantly different between the

**Table 3**
Likert scores of respondent's views on anatomy and radiology teaching.

| Participants were asked to rate[a] their level of agreement with these statements |
| --- |

Q1: 'Anatomical knowledge is important to the field of radiology.' [Base line question]
Q2: 'When leaving medical school, my knowledge of anatomy was sufficient to begin training as a radiologist.'
Q3: 'Junior doctors have an adequate knowledge of anatomy to work in clinical practice'
Q4: 'Radiology was taught as a major component of my preclinical anatomy curriculum'
Q5: 'Radiology and anatomy should be taught in tandem during preclinical teaching'
Q6: 'Using radiology images to compliment anatomy teaching to better prepare students for clinical practice'
Q7: 'Practicing radiologists should deliver radiology based anatomy teaching to preclinical medical students'
Q8: 'Cadavers should remain the cornerstone of anatomy education'

| Grad year | Q1[b] | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1971–1980 | $5.0 \pm 0.00$ | $2.9 \pm 1.06$ | $2.9 \pm 1.21$ | $1.1 \pm 0.38$ | $4.4 \pm 0.98$ | $4.9 \pm 0.38$ | $4.4 \pm 0.98$ | $2.4 \pm 0.98$ |
| 1981–1990 | $5.0 \pm 0.00$ | $3.2 \pm 1.18$ | $2.3 \pm 1.05$ | $1.9 \pm 1.03$ | $4.1 \pm 1.14$ | $4.5 \pm 0.94$ | $4.5 \pm 0.62$ | $3.3 \pm 1.21$ |
| 1991–2000 | $5.0 \pm 0.00$ | $3.7 \pm 1.26$ | $3.0 \pm 1.16$ | $2.1 \pm 1.19$ | $4.5 \pm 0.88$ | $4.7 \pm 0.44$ | $4.4 \pm 0.77$ | $3.7 \pm 1.03$ |
| 2001–2010 | $4.8 \pm 0.97$ | $3.4 \pm 1.22$ | $3.6 \pm 0.62$ | $2.5 \pm 1.38$ | $4.1 \pm 1.03$ | $4.6 \pm 0.62$ | $4.2 \pm 1.03$ | $3.2 \pm 1.03$ |
| 2011–2017 | $4.9 \pm 0.28$ | $2.0 \pm 1.00$ | $2.9 \pm 1.14$ | $2.1 \pm 1.32$ | $4.5 \pm 0.78$ | $4.8 \pm 0.44$ | $4.3 \pm 0.63$ | $3.6 \pm 0.87$ |
| Total | $4.9 \pm 0.50$ | $3.1 \pm 1.27$ | $2.9 \pm 1.09$ | $2.0 \pm 1.20$ | $4.3 \pm 0.98$ | $4.7 \pm 0.64$ | $4.4 \pm 0.80$ | $3.3 \pm 1.08$ |
| Grade | Q1[b] | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 |
| Junior | $4.8 \pm 0.89$ | $1.7 \pm 1.11$ | $3.4 \pm 0.92$ | $2.2 \pm 1.17$ | $4.2 \pm 0.89$ | $4.8 \pm 0.44$ | $4.3 \pm 0.84$ | $3.4 \pm 0.93$ |
| Senior | $5.0 \pm 0.00$ | $3.2 \pm 1.30$ | $2.7 \pm 1.11$ | $2.0 \pm 1.22$ | $4.3 \pm 1.02$ | $4.6 \pm 0.71$ | $4.4 \pm 0.78$ | $3.3 \pm 1.15$ |
| Total | $4.9 \pm 0.50$ | $3.1 \pm 1.27$ | $2.9 \pm 1.09$ | $2.0 \pm 1.20$ | $4.3 \pm 0.98$ | $4.7 \pm 0.64$ | $4.4 \pm 0.80$ | $3.3 \pm 1.08$ |

[a] Ratings were based on a five-point Likert scale with 5 (Strongly agree) and 1 (Strongly disagree).
[b] All data shown are mean $\pm$ standard deviation.

senior (mean rank = 36.75) and junior (mean rank = 27.98) groups when participants were asked whether their level of anatomy was sufficient to begin training as a radiologist upon leaving medical school (Q2; Table 3) ($U = 609.5$, $z = 1.762$, $p = 0.078$), albeit a similar trend was observed when compared to the distribution of responses based on the year of graduation (Fig. 1A). The mean ranks of Likert scores were significantly different when participants were asked whether junior doctors have an adequate knowledge of anatomy to work in clinical practice (Q3; Table 3) ($X^2(4) = 11.978$, $p = 0.018$). These data were complemented by free text comments including 'Had a reasonable undergraduate level of knowledge of anatomy after first year'. 'Had forgotten a good deal of this by the time I started radiology training, and also needed to learn more detail in certain areas' and 'Sufficient to begin training but after one year of radiology training I knew more anatomy than I had ever known in college'. Pairwise comparisons revealed significant differences between the '1981–1990' (mean rank = 23.32) and the '2001–2010' groups (mean rank = 45.32) ($p = 0.006$) (Fig. 1B). In agreement with this, the mean ranks of Likert scores were significantly different between the senior (mean rank = 30.33) and junior groups (mean rank = 42.05) ($U = 314$, $z = -2.391$, $p = 0.017$) (Q3; Table 3). Free text comments included 'The junior doctor may need to revise the anatomy they learned in university and/or gain extra knowledge of anatomy depending on what specialty they work in i.e. greater knowledge of anatomy needed for surgical specialties than medical ones in general', while another stated 'Just about to allow adequate clinical examination but they seem to know very little about radiology and have very little competence in interpreting basic radiological studies'. We found no significant differences in the mean ranks of Likert scores when participants were asked whether radiology was taught as a major component of their preclinical anatomy curriculum (Q4; Table 3) ($X^2(4) = 7.002$, $p = 0.136$) (Fig. 1C), which was confirmed by free text comments including 'Virtually no radiology exposure as a student' and 'Almost no anatomy radiology correlation'. In agreement with this, we also found no significant differences between senior and junior grade radiologists (Q4; Table 3) ($U = 416.50$, $z = -0.953$, $p = 0.341$).

### 3.4. Radiologists' views on integrating radiology into anatomy education

We next asked respondents for their views on the integration of radiology in anatomy education (Q5–7; Table 3). As these questions assessed different elements of the same construct, we calculated the Cronbach's alpha as 0.810, which indicated a high level of internal consistency. We found no significant differences in the mean ranks of Likert scores when participants were asked whether radiology and anatomy should be taught together in preclinical anatomy curricula (Q5; Table 3) ($X^2(4) = 2.736$, $p = .603$) (Fig. 1D), whether using radiological images to compliment anatomy teaching would better prepare students for clinical practice (Q6; Table 3) ($X^2(4) = 1.741$, $p = 0.783$) (Fig. 1E), and whether practicing radiologists should deliver radiology-based anatomy teaching to preclinical medical students (Q7; Table 3) ($X^2(4) = 1.213$, $p = 0.876$) (Fig. 1F) amongst groups with different years of graduation, or between the senior and junior groups for Q5 to Q7 ($p = 0.677$, $p = 0.583$, $p = 0.533$ respectively). There was almost universal agreement between respondents with all of these questions, which was reflected in the mean Likert scores of $4.3 \pm 0.98$ for Q5, $4.7 \pm 0.64$ for Q6 and $4.4 \pm 0.80$ for Q7 (Table 3). Descriptive free comments included 'Radiology is a useful tool in teaching anatomy and familiarity with how anatomy is presented with imaging would be helpful when commencing clinical practice' and 'Yes, I believe radiologists are best placed to do so' and 'definitely only radiologists'.

### 3.5. Teaching methods in anatomy education

We next asked participants for their level of agreement with the statement that the cadaver should remain the cornerstone of anatomy education (Q8; Table 3). We found no significant differences between the groups through different years of graduation ($X^2(4) = 6.913$, $p = 0.141$) nor between senior and junior radiologists ($U = 452$, $z = -0.435$, $p = 0.663$) (graphs not shown). The mean Likert score for this question was $3.3 \pm 1.08$ (Table 3). An informative cross-section of comments included statements such as '3D models, cross-sectional radiology imaging a more than adequate substitute (than cadavers), probably better', 'Nothing can substitute the real human body as a tool to teach anatomy that the students can physically see, touch and maneuver in order to better understand anatomical relationships', 'I think relevant anatomy is better demonstrated by high quality radiology images rather than cadaveric specimens', 'there's a clear role for 'getting your hands dirty' with dissection, it gives a real perspective to anatomy', 'Radiology images are complimentary but should not be used exclusively', 'Both dissection and radiology' and 'All doctors will encounter
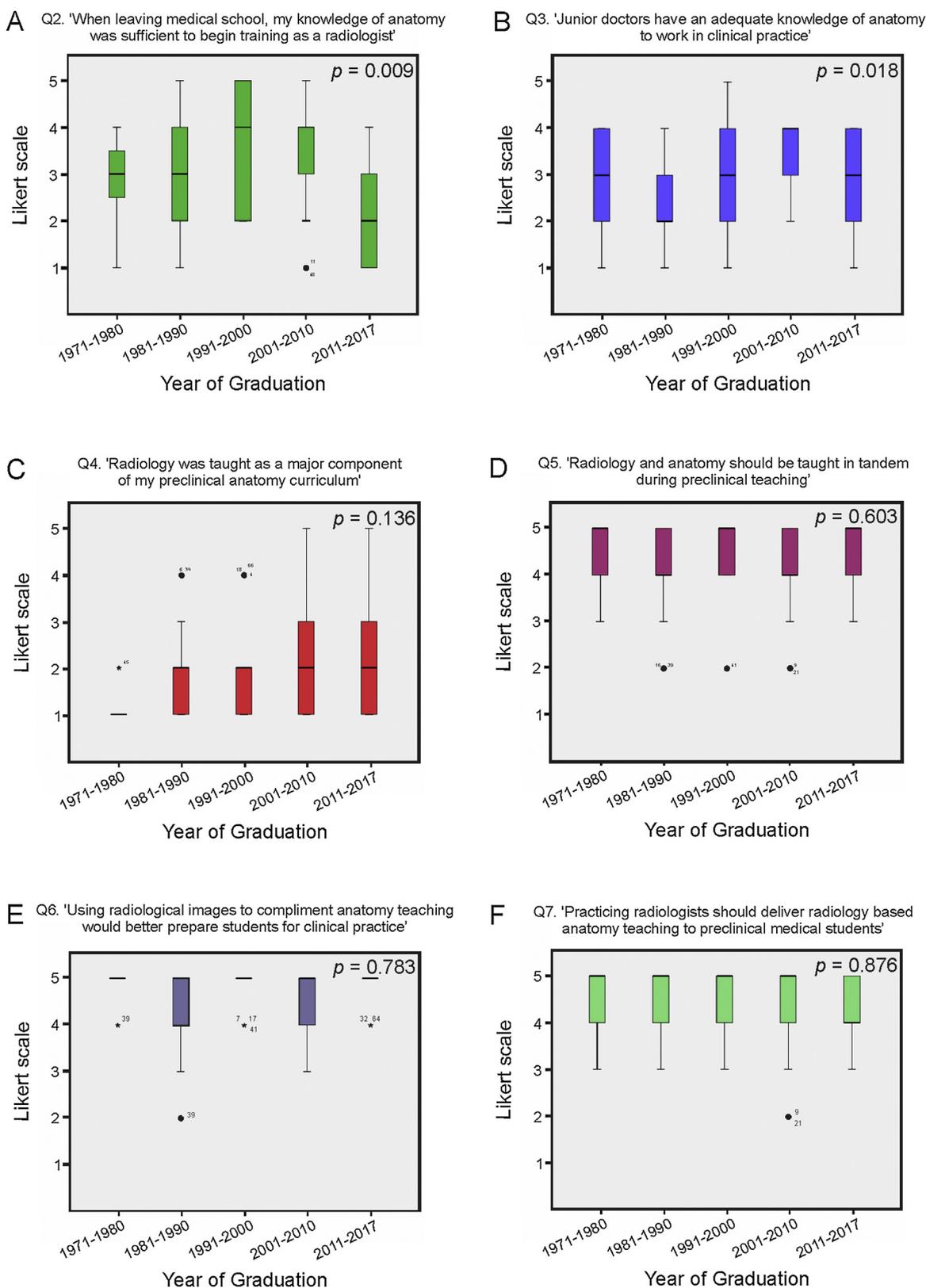
**Fig. 1.** Box plots showing Likert score distributions.
Box plots show the median Likert scale rating responses of participants with different decades of graduation. Box = 25th and 75th percentiles; bars = min and max values. Data were analysed using the Kruskal–Wallis Test with Dunn's post-hoc analysis where appropriate.

scans, few directly encounter the internal contents of a person'. Finally, we asked those surveyed two questions regarding the most beneficial teaching approach and which imaging modality would benefit students most in anatomy education (Q9 and Q10; Fig. 2).

The choices selected in order of preference were; cadavers (50%), radiological images (26.6%), anatomy atlas' (10.9%), lectures (7.8%) and self-directed learning (4.7%) (Q9; Fig. 2A). For images modalities, the majority selected CT (49.3%), followed by 'other' (38.8%),
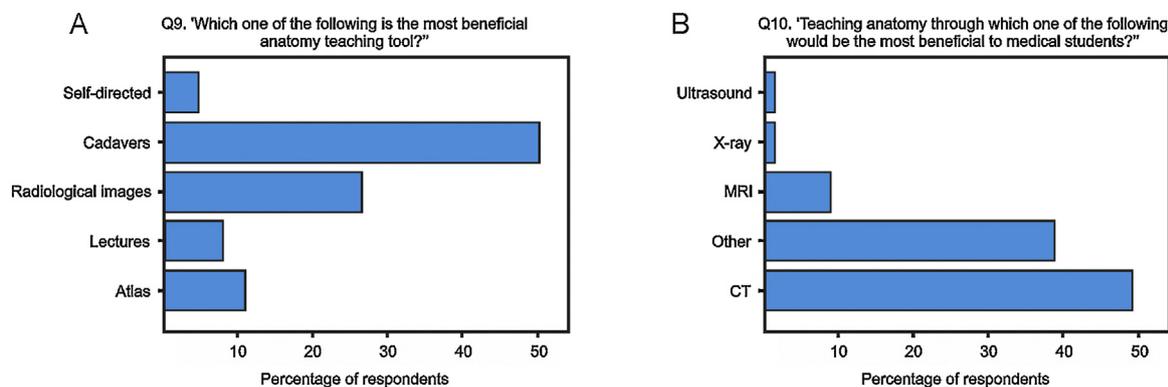
**Fig. 2.** Graphs showing for teaching and imaging modalities.
Graphical representations showing the percentage of respondents who selected (A) the teaching approach they viewed as the most beneficial when teaching anatomy, and (B) which imaging modality if used to teach anatomy would be most beneficial to students. Data are presented as percentage of the total survey population (n = 67).

MRI (9.8%), X-ray (1.5%) and ultrasound (1.5%) (Q10; Fig. 2B). Descriptive free comments included 'All of the above', 'Combination is better', 'A multimodality approach would be best - X-ray, CT and MRI', 'Cross sectional CT and MR would be most beneficial as 3D relationships are nicely illustrated' and 'It depends on what you want to see. MRI for soft tissue and brain. CT for chest, abdo and pelvis and bones etc. Plain X-rays for basic anatomy. Angios for vessels. They are all useful'.

## 4. Discussion

### 4.1. Radiologist views of personal and the junior doctor's anatomical knowledge

Our goals were to consider the perspectives of practicing radiologists on the significance and delivery of radiology teaching in the context of anatomy education. Unsurprisingly, anatomy was considered universally important in preclinical education. However, based on decade of graduation, differences of opinion were observed when asked if their perceived personal anatomy knowledge and that of junior doctors in general was sufficient to begin clinical practice. Radiologists graduating from 2011 to 2017 were significantly less satisfied with their own anatomical knowledge than radiologists graduating from 1990 to 2010, which aligned with the opinions of senior consultant grade radiologists. We noted least satisfaction from senior radiologists, in particular those graduating between 1981 and 1990, when asked for their view on the levels of anatomical knowledge amongst junior doctors. Although this has not been specifically reported in Ireland where medical student numbers are increasing (HEA Factsheet, 2019), the widespread decline in anatomy contact hours and teaching resources does align with these data (Bergman et al., 2008; Drake et al., 2002; McCuskey et al., 2005; Rainsbury et al., 2007; Drake et al., 2009; Craig et al., 2010; Carmichael, 2012; Cho and Hwang, 2013; Raftery, 2007; McBride and Drake, 2018) and agree with the documented lack in anatomy and radiology competency amongst junior doctors and radiologists (Subramaniam et al., 2005; Menon and Rajan, 2006). Moreover, irrespective of decade of graduation, radiologists of senior and junior grades agreed that radiology was not a significant component of their preclinical anatomy curriculum. This is despite the continuous calls by clinicians for formalized radiology teaching and the acceptance of radiology as a signature pedagogy in anatomy, alongside the cadaver (Squire and Novelline, 1985; Gunderman et al., 2003; Linton, 2006). Research has shown that imaging in combination with anatomy specimen offers a greater understanding of the pathological relevance of gross anatomy (Pascual et al., 2011) and enhances the interpretation of radiography in clinical years (Feigin et al., 2007; Dettmer et al., 2010), while

stimulating interest amongst graduates in pursuing radiology as a career (Branstetter et al., 2007). Our survey further showed that the perceived lack of anatomical knowledge is more evident today than for previous generations of medical graduates. The implications of these data and other related research (Prince et al., 2005; Gupta et al., 2008; Roche et al., 2011) is suggestive of an ongoing decline in anatomical insight amongst graduates that may affect the junior doctor's ability to undertake adequate radiological diagnosis in some circumstances.

### 4.2. Developing the radiology curriculum in anatomy education

The second element of our survey gauged radiologist's opinions on the most appropriate teaching practices in anatomy and the people best positioned to teach it. Respondents of junior and senior grade suggested that anatomy and radiology should be merged in anatomy curricula. Respondents stated that radiology did not form a significant component of their undergraduate curriculum. Sourcing anonymized or bespoke digital imaging for teaching purposes has been facilitated by websites such as the wiki-based resources radiopaedia.org© and ultrasoundcases.info©; however, many of these resources are geared toward radiology trainees or residents and do not overcome the limitations faced by non-medically qualified academics in interpreting appropriate radiographs and competently using them as part of a teaching syllabus. Moreover, questions remain as to the most suitable mode into which radiology should be integrated; lectures, problem-based learning, practical instruction or self-directed learning with views being expressed for each (Navsa et al., 2004; Subramaniam et al., 2006; Gregory et al., 2009; Zumwalt et al., 2010; Jang et al., 2018). Likewise, the fundamental technical basis of radiology, tissue types detected and potential clinical implications of pathology often fall outside the remit of the typical preclinical educator and intended anatomical learning outcomes. This partially explains why the amalgamation of radiology into anatomy curricula varies widely amongst institutions (Korner, 1973; Mitchell and Williams, 2002; Craig et al., 2010; Jack and Burbridge, 2012). This was highlighted by the European Society of Radiology which showed that just 26% of 34 surveyed European countries in 2011 integrated radiology into year one medicine (Kourdioukova et al., 2011), while in the US in 2006 radiology accounted for just 5% of the instructional time available to students (Ganske et al., 2006).

### 4.3. Teaching methods in anatomy education

Fifty percent of respondents believed that cadavers should remain the cornerstone of anatomy education which was followed by radiology images, of which CT was deemed most appropri-

ate. Surgeons hold similar mixed views (Sheikh et al., 2016) and considering the recent augmentation of digital and life-like replications and the paucity of instructional time / trained staff required for prosection (McBride and Drake, 2018), these data add to the debate regarding the primary role of the cadavers in anatomy education (McLachlan et al., 2004). Moreover, medical imaging in each of its formats, MRI, X-Ray, CT, and ultrasound imagery readily merge with cadaveric prosections or can replace them entirely (Gunderman and Wilson, 2005; Murakami et al., 2014; Davy et al., 2017). Regardless of grade, our respondents largely believed they themselves are best positioned to deliver radiology teaching. While radiographs have long been described as a component of cadaveric instruction (McNiesh et al., 1983), the activities of radiologists in gross anatomical instruction are dependent on staffing resources and relationships with hospital settings, which is often influenced by proximity or the time considerations of the consultant (Chowdhury et al., 2008; Johnson et al., 2009). Studies undertaken in 2000 and 2002 showed that in the US the presence of radiologists in anatomy departments was below 30% (Samuel and Shaffer, 2000) and less than 20% in the UK and Ireland (Mitchell and Williams, 2002). In Canadian medical schools, the number was reported to be 90% (Jack and Burbridge, 2012).

The variable extent of radiology instruction in anatomy departments, despite the recognition of its importance to junior doctors, is suggestive of a misalignment of syllabus requirements from university and clinical perspectives. A solution is to enhance the association between medical schools and the hospital setting. Technological advances in medical imaging underlying affordability and accessibility are greatly enhancing diagnostics and the dissemination of radiology amongst junior doctors (Nyhsen et al., 2011). As such, the uptake of mobile technologies and their incorporation with picture archiving and communications Systems (PACS), radiology information systems (RIS), in conjunction with digital imaging and communications in medicine (DICOM) protocol standards for storing, encoding, retrieving and transmission of images has revolutionized the practice of radiology and access to diagnostic images across all imaging domains including dentistry, ophthalmology and pathology (Kuzmak and Dayhoff, 1999; Chen, 2001; Noumeir and Pambrun, 2012). While the integration of radiology into preclinical anatomy teaching has existed for decades, digital display platforms are only recently facilitating filmless radiology in practical laboratory teaching (Gregory et al., 2009; Davy et al., 2017) and generally do not involve DICOM, RIS or PACS, at least not for all their intended design purposes. While these systems require significant technical input, increasing demands for expertise in private and public sectoral medical imaging mean that training schemes are being developed (Noumeir and Pambrun, 2012) that will facilitate imaging platforms to operate at clinical and preclinical departmental levels. Furthermore, sharing resources such as trained personnel and PACS, which encode radiology, may represent a collaborative step forward in linking departments of anatomy and their affiliated university hospital counterparts to develop radiology curricula. To our knowledge this is the first documented evidence of radiologists suggesting they wished to contribute more to anatomy education. Considering the decline in the university anatomist (McCuskey et al., 2005; Drake et al., 2009; McBride and Drake, 2018), it is reasonable to predict that radiology oriented professional appointments may fill the void left by the erstwhile anatomy instructor.

## 5. Conclusions

Our data provides acute insights into the perspectives of recently graduated and senior radiologists into the anatomical competency of medical graduates, the role of the cadaver, medical imaging and preferred teaching tools in contemporary medical schools. We received a response rate of 21% which may be considered relatively low, but is in line with a similar report assessing the views of surgeons in anatomy education (Sheikh et al., 2016) and likely reflect the time constraints of the practicing radiologist. We showed that recently qualified radiologists believe that they were insufficiently trained in anatomy to begin clinical practice and in general that radiology was not a significant component of their preclinical curriculum. Moreover, radiologists believed that MR and CT imaging is fundamental to preclinical training, should be merged with cadaveric specimen and that they themselves are best positioned to deliver radiology teaching. Under the spotlight of the changing face of preclinical medical pedagogy, we discuss the significance of these opinions in the context of existing literature and highlight the adaptive roles of anatomy teachers and teaching tools, the curriculum and display technologies in successfully merging radiology into evolving anatomy curricula. It is hoped that future studies may assess the views of the student and the academic on the role of the radiologist in the teaching perspectives of anatomy departments and their further amalgamation into the medical syllabus.

## 6. Ethical Statement

Ethical approval was granted by our institutional research ethics committee, Trinity College Dublin.

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