Clinical Radiology 79 (2024) e1481–e1489

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Interventional radiology procedures, facilities, and workforce across England and Wales: a snapshot retrospective evaluation from 2017 to 2021

G. Najafi [a], R. Lakshminarayan [b], P. Haslam [c], I. McCafferty [d], R. Morgan [e], R. Uberoi [f], M. Hamady [a,*]

[a] *Department of Surgery and Cancer, Faculty of Medicine, Imperial College London SW7 2AZ, UK*
[b] *Department of Vascular Radiology, Hull University Teaching Hospitals NHS Trust, Hull, UK*
[c] *Department of Interventional Radiology, Freeman Hospital, Newcastle, UK*
[d] *Department of Interventional Radiology, University Hospital, Birmingham, Birmingham and Women's NHS Trust, Birmingham, UK*
[e] *Department of Interventional Radiology, Imperial College Healthcare, NHS Trust, London, UK*
[f] *Department of Interventional Radiology, Oxford University Hospitals, Oxford, UK*

ARTICLE INFORMATION

Article history:
Received 9 May 2024
Received in revised form
19 August 2024
Accepted 29 August 2024

AIMS: There is no comprehensive data collection outlining the numbers and types of interventional radiology (IR) procedures in the United Kingdom. Similarly, limited data are available on the IR facilities and workforce within the National Health Services (NHS) trusts. The purpose of this study is to evaluate the number/type of IR procedures, facilities, and workforces across England and Wales.

MATERIALS AND METHODS: This retrospective study used the 2000 Freedom of Information Act to obtain information regarding the IR procedures performed in NHS trusts in England and Wales from 2017 to 2021. We collected additional information on IR workforce and facilities, including the number of IR consultants, nurses, trainees, and angiographic suites and day case units; analysed procedures by complexity; and performed data analysis by region.

RESULTS: A total of 1,340,352 IR procedures were analysed. An increasing trend was observed in the number of IR procedures from 2017 to 2021 (p=0.07, R=0.93). There were more intermediate and complex procedures than simple ones (p=0.0001). Notable geographical variation was observed in terms of IR facilities including angiographic suites and day case units, and the number of IR consultants, nurses, and trainees.

CONCLUSIONS: The IR field continues to grow as evidenced by increasing trends in the number and complexity of the procedures over the years. There is an uneven IR workforce, services, and facilities distribution across England and Wales. Therefore, there is a crucial need for centralised data collection to evaluate and monitor interventions besides comprehensive revision of UK IR service provision.

* Guarantor and correspondent: M. Hamady, Department of Surgery and Cancer, Faculty of Medicine, Imperial College London SW7 2AZ, UK.
E-mail addresses: ghazal.najafi@nhs.net (G. Najafi), raghu.l@nhs.net (R. Lakshminarayan), phil@whichmedicaldevice.com (P. Haslam), ian.mccafferty@nhs.net (I. McCafferty), robert.morgan@stgeorges.nhs.uk (R. Morgan), raman.uberoi@ouh.nhs.uk (R. Uberoi), m.hamady@imperial.ac.uk (M. Hamady).

https://doi.org/10.1016/j.crad.2024.08.032

Introduction

The demand for interventional radiology (IR) services is continuously growing, driven by innovation, evolution of technology, the expanding range of IR procedures across various specialties of medicine and the improvement in clinical knowledge and awareness of IR as a clinical subspecialty. The Royal College of Radiologists identified that the expansion of IR had not met anticipated rates, due to multifactorial reasons, including a shortage in the number of consultants, inadequate nurses and radiographers support as well as limited inpatient or day case beds[1] It had also been predicted in 2020 that there would be an increase of 116 IR consultants over a five-year period in the UK, which would only cover one-third of the previously calculated shortage of IR consultants.[2] This estimation did not take into account the continuously increasing demands and complexities of IR services, which would imply that the shortages are even greater now.

To help improve the future provision of IR services, we need to understand the current demand as well as shortfall in the resources dedicated to provide 24/7 IR services nationally and regional variations in IR provision. Currently, there is no database in the UK covering the number and types of IR procedures, the state of IR facilities, including angiographic suites and day case beds as well as numbers of medical and non-medical IR workforce. Equally important is the need to understand the quality of services provided including the frameworks for ensuring good clinical governance, national audits on IR practice that underpin IR services as well as having appropriate IR tariffs to ensure adequate remuneration of the cost related to IR procedures. To capture the recent state of IR services and infrastructure available in the UK, this retrospective study had three main aims: (1) to analyse the number, complexity, and trend of IR procedures performed within the 5-year period, (2) to evaluate the workforce and resources available for IR services, and (3) to identify regional differences in IR service provision across the UK.

Materials and methods

Ethical approval was not required for the purpose of this study.

Data collection

The Freedom of Information (FOI) Act 2000 was used to contact 122 National Health Services (NHS) trusts across England and Wales. The trusts were asked to submit information regarding their IR procedures, workforce, and facilities during a snapshot period from 2017 to 2021.

Variables collected

Information on the following variables was requested: number and type of IR procedures, number of IR consultants, nurses and IR trainees, number of angiographic suites, and the availability of, and if applicable, the size of day case units.

For the response to the number and type of IR procedures, procedures that were not classified as IR procedures and those that did not have accurate titles, such as those with only procedure codes, were excluded. Non-IR procedures included those that fell under other specialties, such as trauma and orthopaedics, general surgery, gynaecology, cardiology, and diagnostic radiology. Examples of these procedures include but are not limited to orthopaedic pinning of hips, coronary angiography and stenting, pacemaker insertion, laparoscopic fundoplication, barium swallow, and laparoscopic hysterectomy. In addition, trusts with less than five responses for a specific procedure were equated to zero.

Diagnostic radiologists were excluded from the consultant count thereby considering only IR consultants. If numbers for both whole time equivalent (WTE) and total count were provided, WTE was used. To estimate the ideal number of IRs needed for a 100,000 population, the following equation was used. IRs number = the total number of intermediate and complex IR procedures in 2021 × 2hrs (average time of each procedure)/4PAs (typical job plan per week) x 40 weeks divided by the number of 100,000s population according to the 2022 Census. For the number of IR nurses, if a response included a specific number of part-time nurses and WTE, part-time was equated to 0.5 and combined with WTE. For the number of trainees, only IR trainees were included and other radiology trainees were excluded. For the number of angiographic suites, only dedicated IR facilities with C-arm equipment were included. Shared rooms with other specialities, such as hybrid suites and cardiac cath labs, were excluded. For day case units, only those dedicated to IR were included. Shared facilities and recovery areas were excluded.

Procedure classification

The IR procedures were classified from the information provided by the research team based on the procedural complexity into simple, intermediate, or complex. The criteria for this classification system are outlined in Table 1. In addition to this, procedures were also labelled and classified as either vascular or non-vascular. Vascular procedures included those for which the basis of the procedure

Table 1
Classification criteria for IR procedures into simple, intermediate, and complex.

	Simple	Intermediate	Complex
Type of surgery	Day case	Day case or inpatient	Day case or inpatient
Length of procedure	~ 30 mins	Up to 1 hour	Over 1 hour
Anaesthesia required	Local anaesthesia (LA)	LA with/without moderate sedation	Moderate sedation with/without general anaesthesia
Equipment	Single type of equipment (up to £100), may be done at bedside	>1 type of equipment, each or Both costing > £100 < £500	Equipment with cost of ≥ £500
Follow-up required	May be done at bedside, no specific follow-up criterion	Post-op monitoring for at least 2 hours	Inpatient admission or at least 4-hour post-op monitoring

IR: interventional radiology; LA: local anaesthesia

was mainly endovascular, such as angiogram, angioplasty, embolisation, and thrombolysis. Non-vascular procedures included those for which an endovascular approach is not necessary, and examples of these include ultrasound-guided biopsies and aspirations, nephrostomy, and vertebroplasty.

Regional breakdown

For regional breakdown analysis, the data from the trusts within England were divided into the 7 NHS regions, which include (1) east of England, (2) London, (3) midlands, (4) north east and Yorkshire, (5) north west, (6) south east, and (7) south west. For data from trusts in Wales, the entire data was combined and analysed as one region. The population data for the regions of England and Wales was obtained from Census 2021 [1].[1] Our inclusion criteria for considering a region for regional breakdown analysis were to have data from at least half the number of trusts within that region. Ambulance, community, and psychiatric trusts were excluded before assessing if a region met the inclusion criteria.

Statistical analysis

Statistical analyses were performed using GraphPad Prism Software 10 (GraphPad Software Inc). The normality of data was evaluated using Shapiro–Wilk's test.The potential correlations between the number of procedures over the years were assessed by implementing Pearson's correlation. Vascular versus non-vascular procedures were compared using the unpaired *t*-test, with all other tests using one-way analysis of variance (ANOVA) with Tukey's multiple comparisons test. The significant cut off was defined at $p < 0.05$ with a confidence interval of 95%. All figures with error bars report mean with standard deviation unless stated otherwise.

Results

From the 122 NHS trusts contacted, complete responses were received from 116, partial response from 2, and no response from 4 trusts. Among the non-respondents, three were from large tertiary centres. From 2017 to 2021, there were a total of 1,483,425 procedures reported; out of which 1,340,352 were IR procedures. The procedures that were non-IR in nature and those that were not titled properly were excluded (n = 143,073).

Number of procedures 2017–2021

The total number of IR procedures performed in 2017, 2018, 2019, 2020, and 2021 was 256,592, 276,356, 283,172, 232,202, and 292,030, respectively (Fig 1a). For the year 2020, which correlates to the start of the COVID-19 pandemic and the main lockdowns in the UK, there was an 18% reduction in the number of procedures than in the previous year. With the exclusion of 2020, a strongly positive correlation ($p = 0.07$, $R = 0.93$) was observed between the number of procedures over the years (Fig 1b). In 2021, one year following the start of the COVID-19 pandemic, there was a 20.5% increase in the number of procedures than in 2020.

Types of procedures by complexity

Over the five-year period, a total of 345,902 simple, 674,401 intermediate, and 320,049 complex procedures were performed across the trusts in England and Wales. On average, 66,066 ± 5,167, 131,518 ± 12,703, and 62,289 ± 5,898 procedures were performed per year that were simple, intermediate, and complex, respectively (Fig 2a). There were significantly more intermediate complexity procedures than simple ($p = 0.0001$) and complex ($p < 0.0001$) procedures, with no difference ($p > 0.05$) between the numbers of simple and complex procedures.

Vascular vs non-vascular procedures

From 2017 to 2021, a total of 423,235 vascular and 917,117 non-vascular procedures were performed across the trusts. (Fig 2b).

Procedures per population by region

All regions in England and Wales met the inclusion criteria with at least half of the number of trusts included within each region (Table 2). The total number as well as the average yearly number of procedures per 100,0000 per region can be found in Table 2. Wales had 767 procedures per 100,000 on an average yearly basis, which was the highest

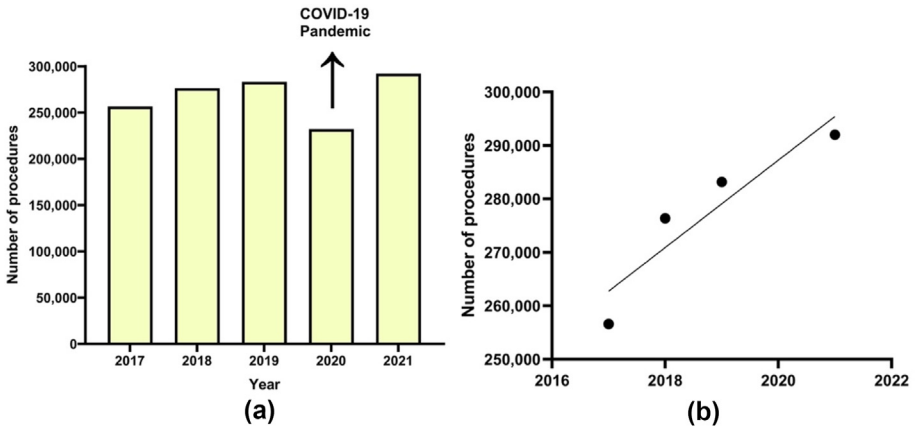

Figure 1 (a) The yearly total number of IR procedures performed across all trusts covering 2017 to 2021. (b) When excluding the data from 2020, a linear increase in the number of IR procedures performed per year is observed ($p = 0.07$, R = 0.93). IR: interventional radiology

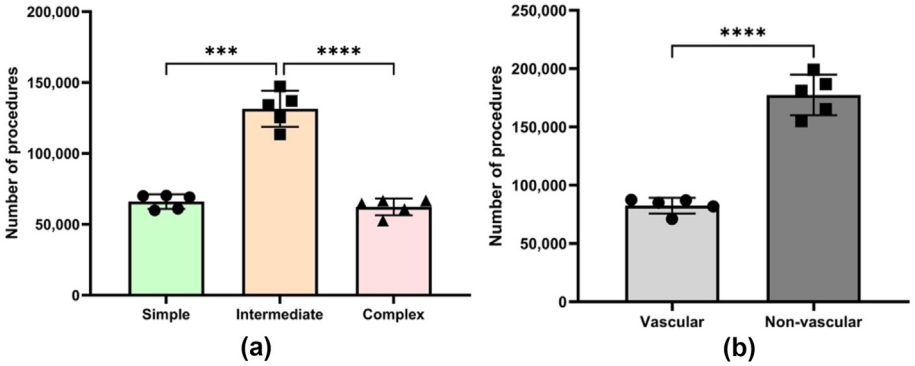

Figure 2 (a) Average number of procedures performed per year based on complexity (Mean ± SD, ***$p = 0.0001$, ****$p < 0.0001$ using one-way ANOVA with Tukey's multiple comparisons test). (b) Average number of vascular versus non-vascular procedures performed per year (Mean ± SD, ****$p < 0.0001$ using two-tailed unpaired *t*-test).

out of all the regions. This was followed by north east and Yorkshire, London, and north west with 550, 535, and 535 average yearly procedures per 100,000, respectively. Next were east of England and south east which had 437 and 371 average yearly procedures per 100,000, respectively. Lastly, the lowest number of average yearly procedures was reported by south west, with 198 procedures per 100,000. Overall, there was substantial geographical variation in terms of average number of IR procedures performed on a yearly basis (Supplementary Fig 1).

In addition, the yearly average number of complex procedures per 100,000 showed significant variation amongst different regions (Fig 3). Regions including north east and Yorkshire, London, and Wales had significantly higher

Table 2
The number of trusts per region within England from which responses were collected. All regions met the inclusion criteria with a minimum of 50% of all their trusts included. Percentages have been rounded to one decimal place. Regional breakdown of the number of procedures per 100,000 population. The values were rounded to whole numbers.

Region	Trusts with collected responses/total trusts within the region	Total number of procedures (2017–2021) per 100,000	Yearly average number of procedures per 100,000
East of England	10/18 (55.6%)	2,184	437
London	16/28 (57.1%)	2,675	535
Midlands	21/34 (61.8%)	1,824	365
North east and Yorkshire	19/21 (90.5%)	2,752	550
North west	20/26 (76.9%)	2,673	535
South east	16/24 (66.7%)	1,855	371
South west	10/15 (66.7%)	990	198
Wales	N/A	3,835	767

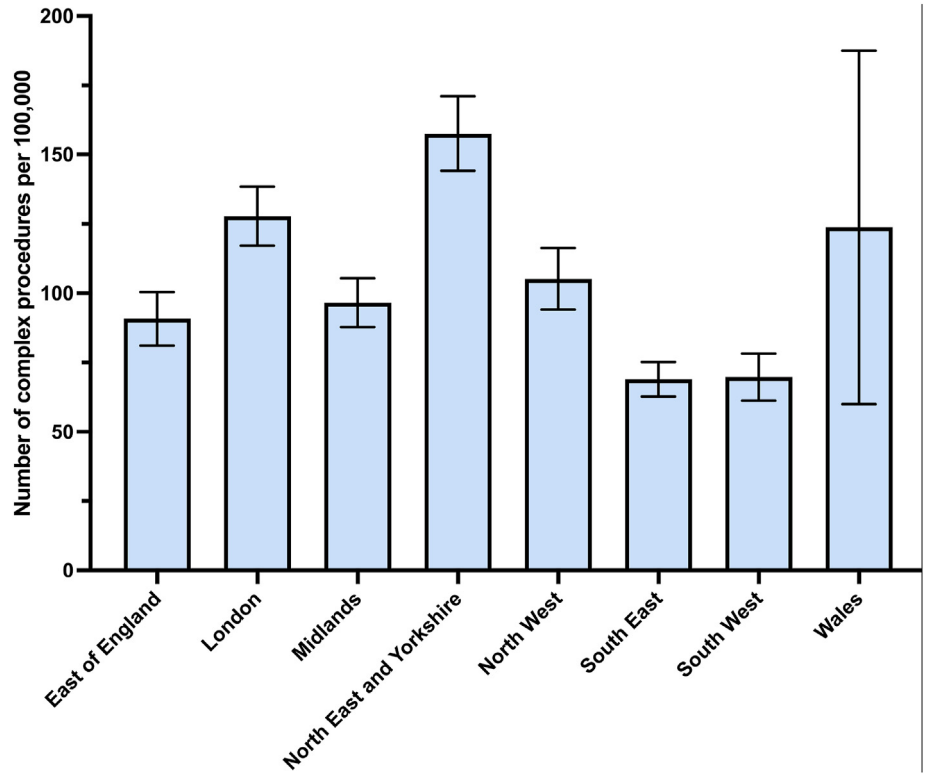

Figure 3 The yearly average number of complex procedures per 100,000 population by region (Mean ± SD). London and Wales had higher number of complex procedures when compared to south east and south west ($p < 0.05$). North east and Yorkshire had higher number of complex procedures compared to north west ($p < 0.05$), south east ($p < 0.0001$), south west ($p < 0.0001$), the midlands ($p < 0.01$), and east of England ($p < 0.01$). There was no difference in numbers between all other regions. All statistical tests were performed using one-way ANOVA with Tukey's multiple comparisons test.

numbers of complex procedures than those in the south west and the south east ($p < 0.05$).

IR workforce by region

Across the 118 trusts, in 2021 there were a total number of 561 IR consultants, 982 IR nurses, and 103 IR trainees.

In terms of response to the number of IR consultants, seven trusts did not provide an answer to the number of IR consultants. Regions including north west, Wales, north east, and Yorkshire had the highest numbers of IR consultants per 100,000 population, and regions including south west, east of England, and south east had the lowest numbers of IR consultants per 100,000 (Fig 4a). Based on the number of intermediate and complex cases performed in 2021 only and the proposed equation mentioned in the methods section, the ideal number of IR consultants per 100,000 population is estimated at 11/100,000.

Additionally, four trusts did not provide an answer to the number of IR nurses within their trusts. Again, there was notable regional variation in the number of IR nurses, with regions such as London, east of England, and north east and Yorkshire reporting the greatest number of IR nurses per 100,000, and Wales and south west reporting the least number of IR nurses per 100,000 (Fig 4b).

Lastly, 33 trusts did not provide a response to the number of IR trainees within their trusts. London reported the highest number of IR trainees at 0.33 per 100,000 population, whereas south west had the least number of IR trainees with 0.035 per 100,000 population (Fig 4c).

IR facilities—angio suites and day case units/beds by region

In 2021, across the 118 trusts, there were a total of 194 angiographic suites and 44 dedicated day case units with a total of 269 beds.

Regions with the highest numbers of angiographic suites available to IR services included the Midlands (n = 39), North east and Yorkshire (n = 35), and South east (n = 30), and those with the least numbers of angio suites included North west (n = 18), South west (n = 18), and Wales (n = 9) (Supplementary Fig 2).

Furthermore, 44 trusts reported the presence of a day case unit available to IR services, 72 trusts reported no day case unit availability, and 2 trusts did not respond. The regions with the highest number of IR day case units included south east (n = 10), north west (n = 7), and the midlands (n = 7). East of England (n = 4), north east and Yorkshire (n = 4), and Wales (n = 1) expressed the least number of day case units (Fig 5a). The regions with the greatest number of beds in the day case units were south east (n = 49), south west (n = 46), and the midlands (n = 42), respectively. Those with the least number of beds in the day case units were north

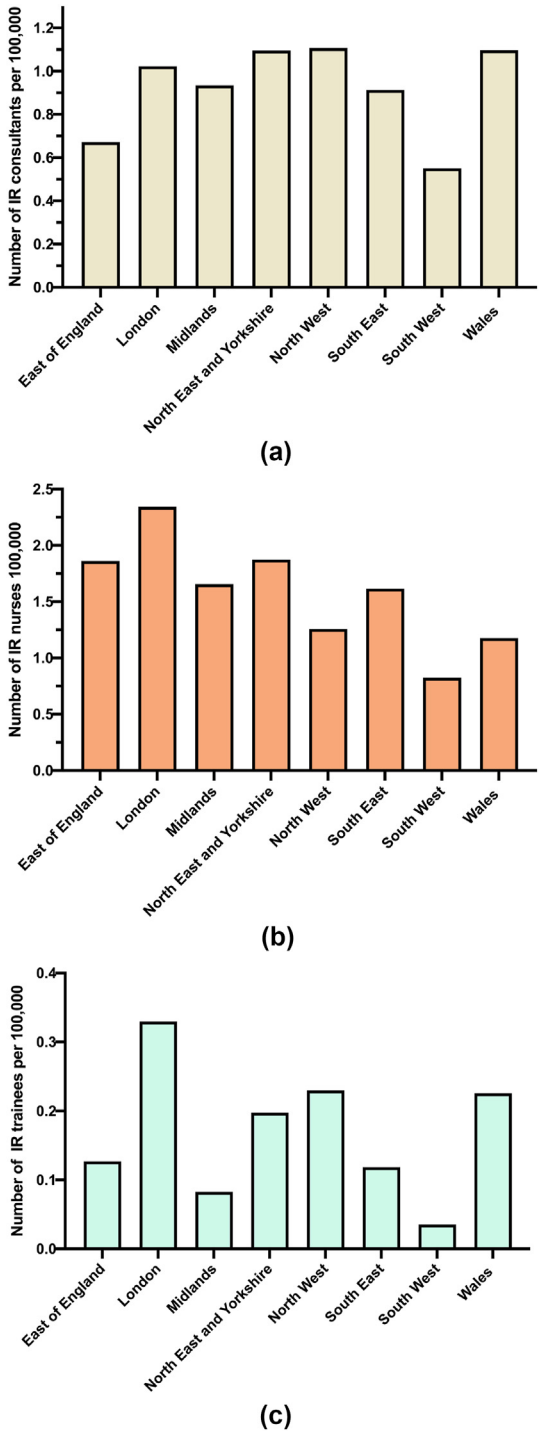

Figure 4 The regional breakdown for the number of (a) IR consultants, (b) IR nurses, and (c) IR trainees per 100,000 population in 2021. (a) There is regional variation in number of IR consultants with south-west, east of England, and south east having the least number of IR consultants per 100,000. (b) Similarly, south west, Wales, and north west reported the least number of IR nurses per 100,000. (c) The highest number of IR trainees per 100,000 was reported by London, followed by north west and Wales, respectively. IR: interventional radiology

west (n = 28), north east and Yorkshire (n = 25), and Wales (n = 4), respectively (Fig 5b).

Discussion

To inform future planning of interventional radiology (IR) services in England and Wales, we provide valuable data regarding the numbers and trends in IR procedures, facilities, and workforces across the United Kingdom from 2017 to 2021. In line with previous predictions of increasing demands on IR services across the United Kingdom,[2] we found increasing numbers of IR procedures have been performed from 2017 to 2021. Despite the beginning of the COVID-19 pandemic acting as an obstacle in 2020, the number of IR procedures rapidly increased again in 2021. This was mainly due to the minimally invasive nature of IR procedures, the fact many procedures did not require general anaesthesia, and the high technical and clinical success. In addition, there has been a significant increase in the range of IR procedures in various fields of medicine. There may have also been a shift in IR procedural coverage during the pandemic, where the value of day case service and the minimally invasive nature of IR came to the fore. For example, IR physicians were asked to perform procedures, such as venous access and drainages,[3] as well as some procedures usually covered by other services, such as gastrostomy.[4] Overall, this illustrates the resilience and adaptability of IR service provision in the face of a national health crisis.

In this study, we confirmed the demand and utilisation of IR services has increased significantly, despite a major shortage in the workforce. This increasing pressure on the IR workforce is likely one of the reasons for burnout in IRs, as illustrated in a recent UK survey.[5]

One of the main NHS tenets is equality of service and care provision. This study has shown that there exists an inequality in the ratio of IR procedures conducted per 100,000 population per region over the studied period of five years (Fig 3) and an obvious postcode lottery. In addition, there were disparities in the number of complex procedures, taking place in different regions (Fig 4). Many of these complex procedures require more advanced equipment, accessible facilities, and adequate staffing. In terms of staffing, in 2023 in the United Kingdom, the The Royal College of Radiologists (RCR) census reported there were 13.1 WTE IR consultants per million—though with significant variation across regions.[1] Similarly, we identified differences between regions regarding the number of IR consultants, such as London and south-west reporting 11 and 5.5 consultants per million, respectively. This may highlight the difficulty in maintaining IR services in more rural and suburban regions of the country. A US-based study by Findeiss *et al.* described challenges in the recruitment and retention of IR consultants to small and rural regions, the lack of infrastructure to support IR services in these

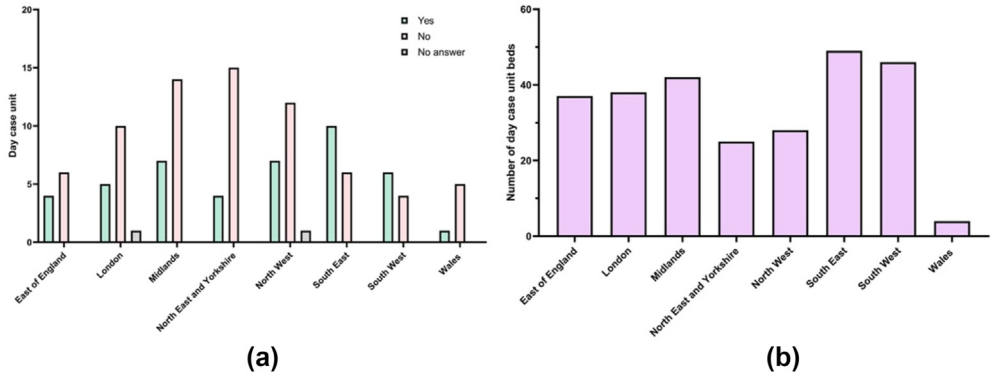

Figure 5 The regional breakdown analysis for day case units. (a) The presence of day case units per region. 'Yes' and 'No' responses were obtained, with two trusts not providing an answer. (b) The number of day case unit beds present within each region.

regions, and the importance of creating sustainable IR services in small and rural hospitals to reduce health care disparities.[6] There is no standardised method to work out the ideal number of IR consultants per 100,000 population in the United Kingdom. The Provision of Interventional Radiology Services[7] report suggested a minimum 1:6 to 1:8 on-call staffing per trust. According to the data generated in this report, we proposed an equation that considers the number, complexity, and time of procedures performed in 2021 against the typical job plan operating time of a consultant IR. There is an estimated need of 11 IR consultants per 100,000 people. It is understood that some IR procedures are done by general radiologists, especially in district general hospitals. However, the authors believe that intermediate complex interventions (like varicocele embolisation) and complex ones (angioplasty/stent, ablation, etc) are done by IR-trained operators irrespective of the title they wish to use. Therefore, for training and workforce planning, operators doing complex procedures or even several intermediate procedures like embolization should receive adequate procedure and clinical training and be considered as part of the team delivering IR services. Irrespective of the calculation method, the number of consultant IRs is currently far from satisfactory, which can explain in part the burnout results published by Al Rekabi *et al.*[5]

Regional variation was also observed regarding the number of IR nurses, and this was even greater between some regions. For example, London reported 2.4 IR nurses per 100,000 people, whereas south-west reported 0.8 per 100,000.

Lastly, many NHS trusts did not keep records of the exact number of IR trainees within their trust at the time of response, as evident by the lack of responses. Regional variation in the number of IR trainees was again observed. For example, the trainee number in south-west and the midlands was 0.035 and 0.083 IR trainees per 100,000 people, respectively, which likely reflects missed opportunities in providing IR trainee posts across the United Kingdom. In turn, this emphasises that the need for increasing IR training posts to meet the rising demand for IR services is likely still unmet.[2]

In addition to the workforce, there is regional variation in the availability of IR facilities, including angiographic suites and day case units. The low numbers of angiographic suites reported in regions such as South West and Wales could mean reduced capacity to perform certain procedures, especially those that are more complex in nature. This is reflected in the number of complex procedures per region. For example, in Wales, despite reporting the highest number of average yearly procedures per 100,000 people, it saw the lowest number of yearly complex procedures. Similarly, there was low availability of day case units—and beds within those units. The regional variation in the availability of day case units, with some trusts reporting no day case units and some with limited numbers of beds, limits the number of day case IR procedures that can be conducted. If more day case units were available to IR facilities, it would allow for room to facilitate the current backlogs of IR services—and ultimately further expansion of noninvasive IR services offered to patients,[1,7] as well as relieve pressure on hospital beds and improve the patient experience.

Hospital IR units rely on several factors to function at optimal capacity. These factors include staffing, such as IR consultants, nurses, trainees, and radiographers. In addition, facilities must be available to the IR services, including angiographic suites, adequate and appropriate equipment, and day case units and beds. An optimal combination of these factors will lead to maximisation of IR services productivity; this combination continues to be undefined, and, as a result, remains unachieved across many sites in the United Kingdom.

The main way to understand the need to achieve a standard level of IR service provision across the United Kingdom, monitor the quality of care and identify areas of cost saving is through a robust and centralised data registry.

Previously, there have been useful but limited national efforts to assemble registries on specific IR applications, such as the British Society of Interventional Radiology Inferior Vena Cava registry[8] and the iliac angioplasty and stent registry.[9] In addition, it has been shown that certain IR interventions such as the treatment of benign prostate hyperplasia, uterine fibroids embolization and chest port insertions are more cost-effective than their non-IR counterparts with similar safety outcomes.[10–15]

If we accept that the ongoing and future needs of patients are best served by minimally invasive image-guided

therapy enabling short hospital stays (day case procedures) and recovery times, investing in IR service provision should yield enormous financial benefits to the NHS and society at large.

The authors believe that the revision of services should include a) networks of on-call provision where the spoke and hub model is implemented to provide flexibility and resilience; (b) day case models of spoke and hub, which should follow the same distribution of vascular centres to combine forces and make the best use of human and equipment resources; (c) national registry under the auspice of the Royal College of Radiologists to monitor clinical outcomes and equipment performance linked to cost; and (d) increase IR training posts within radiology numbers to match resource availability and service needs.

However, this study had a few limitations: First, it is important to note data was neither captured from all trusts nor from Scotland centres due to limited resources available to the research team. However, the trend in the study findings will likely be, by and large, applicable to Scotland and Ireland regions. Second, the classification criteria for the complexity of procedures were subjective in nature. However, the authors used this classification based on the typical time and cost of each procedure, which has potential implications for the workforce and resources. Third, the trusts exhibited poor and inconsistent coding of procedures, which could lead to underestimation of IR procedures or vice versa. However, we tried to mitigate this by providing general guidance to the Freedom Of Information Act officers using a comprehensive list of IR codes. Lastly, no temporal change in IR facilities and workforce could be obtained because only a snapshot of the final year was provided.

Conclusions

An increasing trend has been observed in the number and complexity of IR procedures from 2017 to 2021, despite an imbalance in the provision and demand of IR services. There is notable variation in IR service provision across England and Wales and a striking lack of records regarding safety and services cost data in the United Kingdom. Therefore, there is a crucial need for centralised and harmonised data collection of IR procedures to understand the scope and breadth of IR work, to monitor clinical outcomes and safety, and to assess the cost and impact on IR workforce and training opportunities.

Authors contributions

1. Guarantor of integrity of the entire studyMohamad Hamady
2. Study concepts and design Mohamad Hamady, Raghu Lakshminaranan, Philip Haslam
3. Literature researchGhazal Najafi, Mohamad Hamady
4. Clinical studiesGhazal Najafi, Raghu Lakshminaranan, Mohamad Hamady
5. Experimental studies/data analysisGhazal Najafi, Raghu Lakshminaranan, Mohamad Hamady
6. Statistical analysisGhazal Najafi
7. Manuscript preparationGhazal Najafi
8. Manuscript editingRaghu Lakshminaranan, Raman Uberoi, Robert Morgan, Ian McCafferty, Philip Haslam

Conflict of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: M Hamady reports administrative support was provided by The British Society of Interventional Radiology. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by Imperial College London Healthcare Biomedical Research Centre and the British Society of Interventional Radiology.

List of abbreviations

IR	Interventional Radiology
FOI	Freedom of Information Act
WTE	Whole Time Equivalent
IVC	Inferior Vena Cava

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crad.2024.08.032.

References

1. Radiologists, R.C.o. *RCR clinical radiology workforce census*. Royal College of Radiologists; 2022.
2. Morgan R, Cleveland T, Hamady M, *et al*. Interventional radiology in the 21st century: planning for the future. *Clin Radiol* 2021;**76**:865–9.
3. Sarwar A, Shanafelt TD, Sze DY, *et al*. The threat to the soul of interventional radiology escalated by COVID-19. *J Vasc Interv Radiol* 2023;**34**:945–9.
4. Woerner A, Chick JFB, Monroe EJ, *et al*. Interventional radiology in the coronavirus disease 2019 pandemic: impact on practices and wellbeing. *Acad Radiol* 2021;**28**:1209–18.
5. Al Rekabi A, Chen M, Patel N, *et al*. Well-being and burnout amongst interventional radiologists in the United Kingdom. *Cardiovasc Intervent Radiol* 2023;**46**:1053–63.
6. Findeiss LK, Everett C, Azene E, *et al*. Interventional radiology workforce shortages affecting small and rural practices: a report of the SIR/ACR joint task force on recruitment and retention of interventional radiologists to small and rural practices. *J Am Coll Radiol* 2022;**19**:1322–35.
7. British society of interventional radiology. https://www.bsir.org/media/resources/files/BSIR_2023_IRProvisions (accessed May 2024).
8. Uberoi R, Tapping CR, Chalmers N, *et al*. British society of interventional radiology (BSIR) inferior Vena Cava (IVC) filter registry. *Cardiovasc Intervent Radiol* 2013;**36**:1548–61.
9. Miller C, Frood R, See TC, *et al*. British society of interventional radiology iliac angioplasty and stent registry: fourth report on an additional 8,294 procedures. *Clin Radiol* 2019;**74**:429–34.

10. Caplin DM, Young S, Kassin M, *et al*. A history and modern framework for quality improvement in interventional radiology. *J Vasc Interv Radiol* 2023;**34**:2012–9.
11. Tsetis D, Uberoi R, Fanelli F, *et al*. The provision of interventional radiology services in europe: CIRSE recommendations. *Cardiovasc Intervent Radiol* 2016;**39**:500–6.
12. LaRoy JR, White SB, Jayakrishnan T, *et al*. Cost and morbidity analysis of chest port insertion: interventional radiology suite versus operating room. *J Am Coll Radiol* 2015 Jun;**12**:563–71.
13. Bulman JC, Malik MS, Lindquester W, *et al*. Research consensus panel follow-up: a systematic review and update on cost research in IR. *J Vasc Interv Radio* 2023;**34**:1115–25. 2023.
14. Janne d'Othée B, Faintuch S, Reedy AW, *et al*. Retrievable versus permanent caval filter procedures: when are they cost-effective for interventional radiology? *J Vasc Interv Radiol* 2008;**19**:384–92.
15. Shivakumar V, Bundorf M, Kothary N. 4: 21 PM Abstract No. 126 the role of physician-driven device preferences in cost variation of common interventional radiology procedures. *J Vas Interv Radiol* 2020 Mar 1;**31**.