ORIGINAL STUDY

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Decreasing exposure to thyroid radiation in an orthopaedic theatre setting: an educational intervention

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The use of personal protective equipment (PPE) can significantly reduce staff exposure to harmful radiation and infection. Fluoroscopic procedures in orthopaedic theatre can generate high levels of radiation and good adherence to PPE use is essential to reduce long term cancer risk, including thyroid cancer.

To assess baseline compliance with PPE, availability of PPE in theatre and carry out an intervention to promote greater use of PPE.

This was a closed-loop interventional study set in a level 1 trauma centre and an elective/rehabilitation unit. Data were collected in 40 cases pre and post-intervention from 26th May-7th July 2017. All health care practitioners present at fluoroscopic screening were observed. PPE availability was audited daily. A questionnaire was used to assess surgical and nursing knowledge/practices regarding radiation/infection safety. An educational presentation was delivered to the groups at highest risk of exposure.

39/41 questionnaires were completed (29 surgeons, 10 nurses). 41% of respondents had taken a radiation training course or felt they had adequate training. There was a significant increase in the use of thyroid guards by surgeons 13/115 (11.3%) pre-intervention to 54/117 (46.2%) post-intervention ($p<0.001$) and radiographers ($p=0.019$) post-intervention. Logistic regression showed an 89.7% increased likelihood of thyroid guard use post-intervention and a 12.7% increased chance of thyroid guard use for each extra guard available.

A short educational, easily replicated session, significantly improved compliance with thyroid guards by orthopaedic surgeons.

Key words: PPE, thyroid, orthopaedics, radiation, guard.

INTRODUCTION

Personal protective equipment (PPE) protects both staff and patients from infection, radiation and injury. The orthopaedic theatre is a high-risk environment for exposure to infection and radiation, due to the physical nature of orthopaedic procedures, use of power tools and increasing utilisation of fluoroscopy.

Lead aprons are the highest compliance shielding tool; protection reduces an individual's risk to cancers in many organs including the lungs, stomach, colon, bone marrow etc. The thyroid glands position makes it particularly susceptible to scatter radiation during fluoroscopy, which with cumulative exposure increases the risk of thyroid carcinogenesis. Yet thyroid guards are commonly reported as having poor utilisation in orthopaedic theatres[1-7].

The 'As Low as Reasonably Achievable' (ALARA) guidelines have three basic principles designed to minimise occupational radiation exposure[8-10]: reduction in exposure time, distance from radiation source and shielding. In orthopaedic surgery, shielding is the easiest variable to control, as time and distance are difficult to mitigate[4,5,11,12]. Staff compliance with and the correct use of shielding equipment are readily modifiable risk factors. This can be facilitated by increasing PPE availability; publication of guidelines; and ongoing education of staff [8,13-18].

The aim of this study was to assess current practice and knowledge and to design an educational intervention to improve the compliance with PPE in fluoroscopically guided orthopaedic procedures.

MATERIALS AND METHODS

This was a closed loop interventional study. The setting was a level 1 trauma centre and elective/rehabilitation unit in Cork, Ireland. The intervention was directed to

Table I. — Pre-study questionnaire (staff frequency of PPE use)

Which protective equipment did respondents use? (respondents asked to identify use as always/often/ occasionally/seldom/never)		
Thyroid guard	Always/often	17/39 (43.6%)
Lead apron	Always/often	36/39 (92.3%)
Visor	Always/often	18/39 (46.2%)
Radioprotective eyewear	Never	33/39 (84.6%)
Increasing source distance	Always/often	19/39 (48.7%)
Minimal fluoroscopic time	Always/often	17/39 (43.6%)
Visors	Always/often	18/39 (46.2%)
Dosimeter	Never	23/39 (59.0%)

Table II. — Pre-study Questionnaire (Participant prior radiation training, knowledge of risks, ALARA guidelines and basic safety practices)

Guideline, knowledge or safety practice	**Response rate**
Radiation training perceived to be adequate	16/39 (41%)
Aware of ALARA principle/guidelines	9/39 (23.1%)
Used dosimeter within last year	6/39 (15.4%)
Aware of minimum safe distance i.e. 2 metres	8/39 (20.5%)
Additional protection required in pregnancy	29/39 (74.4%)
Appropriate measures to reduce exposure in pregnancy	16/39 (41.0%)
Aware of risk of infection from eye contamination	39/39 (100%)
Seroconversion rate correct HIV	3/39 (7.7%)
Seroconversion rate correct Hepatitis B	6/39 (15.4%)
Seroconversion rate correct Hepatitis C	0/39 (0%)

orthopaedic surgeons and nurses from both centres. Data collection took place between 12th May and 7th July 2017, observing a pragmatic sample size of 40 cases pre and post-intervention to allow adequate time for study completion prior to staff rotation in July.

A baseline questionnaire elicited knowledge of standard radiation protocols, infection risks and staff practices (Table 1). A key component of the questionnaire assessed whether the health care professional recognised the source of radiation from the C-arm by correctly identifying the X ray tube, see Figure 1. The questionnaires were augmented from a previous study by Nugent et al.[3]. All surgical consultants and trainees (n=31) in addition to an opportunistic random sample of orthopaedic nurses (n=10) were invited to participate and received a questionnaire. All questionnaires were collected prior to the intervention, no questionnaires were excluded.

The author (CD) monitored PPE compliance during orthopaedic procedures requiring fluoroscopic guidance by all staff entering theatre during each case from 26th May to 8th June and 23rd June to 7th July 2017 for pre-and post-intervention respectively.

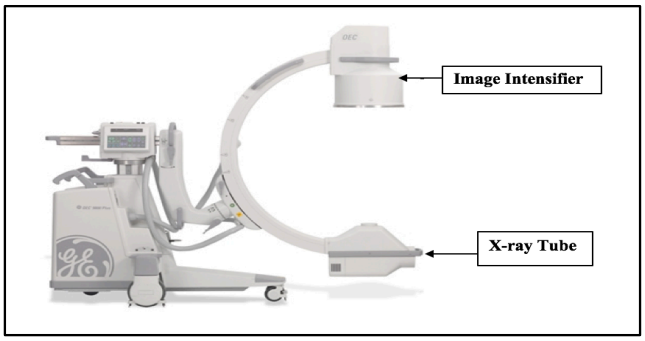

Figure 1. — Diagram of C-arm with labelled parts ("X-ray Tube" is the radiation source, "Image Intensifier" assists in the production of the x-ray image).

An observation sheet was utilised to standardise study observations (Table 3). Staff were unaware of the purpose of monitoring. PPE availability was audited each morning prior to commencement of procedures. Only surgeons and nurses were observed for visors. Procedures broken into separate definable parts were considered individual procedures. The intervention was delivered to four groups to target as many staff from both centres as possible.

The educational intervention was based on observation during the study period and analysis of questionnaire responses (n=39) from orthopaedic staff in both centres. The intervention was delivered at departmental meetings in a PowerPoint presentation format.

Data were analysed with IBM SPSS statistical software (version 23) using descriptive statistics, chi-square analysis, Fischer exact tests and binary logistic regression. Ethical approval was granted by the UCC Clinical Research Ethics Committee.

RESULTS

Individuals were 90% more likely to use a thyroid shield post-intervention (p=0.001). There was a 13% increased chance of a thyroid shield being used for each extra shield made available to staff (p=0.009). Radiographers were found to be 4-times, 9-times and 6-times more likely to use a thyroid shield when compared to surgeons, anaesthetists and the 'others' group respectively (p<0.001).

Only a minority of participants self-reported use of thyroid guards and eye wear compared to lead aprons which had almost full compliance. Of note, lead aprons were being worn correctly.

Table III. — Pre-and post-intervention compliance levels stratified by occupation. Only surgeons and nurses were observed for visor use as they are in high-risk proximity to splashes. Radioprotective eyewear and gloves were not worn in any procedure.

Occupation	PPE type	Pre-intervention	%	Post intervention	%	P-value
Surgeon	Lead apron	110/116	94.8	116/117	99.1	0.066
	Thyroid shield	13/115	11.3	54/117	46.2	<0.001
	visor	38/97	39.2	13/91	14.3	<0.001
Nurses	Lead apron	95/97	97.9	112/114*	98.2	1.000
	Thyroid shield	54/96	56.3	64/115****	55.7	1.000
	visor	2/81	2.5	8/100	8.0	0.189
Radiographer	Lead apron	57/57	100	51/52	98.1	0.477
	Thyroid shield	28/56	50.0	37/51	72.5	0.019
	visor	N/A		N/A		
Anaesthetist	Lead apron	41/41**	100	55/58***	94.8	0.265
	Thyroid shield	7/40	17.5	10/57*****	17.5	1.000
	visor	N/A		N/A		
Other	Lead apron	38/39	97.4	11/13	84.6	0.151
	Thyroid shield	9/39	23.1	1/13	7.7	0.419
	visor	N/A		N/A		

*1/112 used lead screen & 2/112 exited during screening instead of using lead apron respectively; ** 6/41 used a lead screen instead of using a lead apron; *** 1/55 exited during screening instead of using a lead apron; **** 2/64 exited theatre during screening instead of using a thyroid shield; ***** 1/10 exited theatre during screening instead of using a thyroid shield.

Table IV. — Mean measures of radiation exposure per theatre case

Measure:	Mean (all cases)	Mean (upper limb)	Mean (lower limb)
Screening time (seconds)	48.35	30.48	62.48
Dose Area Product (Centigray/cm^2)	63.94	15.58	102.17

The most common reasons for not using thyroid guards were; 'unavailable', forgot and uncomfortable respectively (25.6%,12.8%,10.3%). 20.5% of participants chose 'did not care' as a response when asked about the use of visors). 43.6% reported radioprotective eyewear as unavailable with a further 25.6% not knowing this was an option.

Less than half of participants (48.7%) could correctly identify the radiation source on the C-arm used in theatre. Further to this, only 33.3% and 20.5% could identify the ideal position of the C-arm in the vertical and horizontal planes respectively for the reduction of radiation exposure.

The mean availability of thyroid guards (5.46) was less than one-third that of lead aprons (17.35) which is certainly a potential contributor to compliance issues. Mean daily visor availability was always in surplus to demand (38.81).

41 people took part in the educational intervention, this comprised six Consultants, eleven Registrars, three Senior House Officers, nine Interns and twelve theatre nurses.

Mean intraoperative exposures for the study are illustrated in table 4.

DISCUSSION

Radiation exposure presents an inherent and easily modifiable risk to the health of orthopaedic surgeons [5]. Several factors can prevent or reduce use of these risk modifiers; especially thyroid shields. These include knowledge or training deficits, lack of perceived risk and lack of availability. Our study demonstrates that there are deficiencies in all three areas.

There is a clear knowledge deficit pertaining to radiation safety. 41% of participants had never taken a formal radiation protection course. The surgeons, due to proximity to the radiation source are at highest risk[4,5]. Surgical staff in training have regular, high turnover rates and radiation protection certification is

not centrally monitored in Ireland making it difficult for individual hospitals to police.

The three ALARA principles are time, distance and shielding. This study has demonstrated an underuse of shielding, particularly regarding thyroid guards. The intervention resulted in a significant increase in the use of thyroid guards by surgeons, the highest risk staff ($p<0.001$). Timing is difficult to modify as it primarily depends on the surgeon's level of experience[11,12]. Additionally, dose rate can vary significantly depending on factors other than screening time such as tube current and frame rate. Likewise, it is difficult to increase distance from the source as surgeons are often required to maintain source proximity for joint manipulation etc. Where possible, staff should retire from the operating table during screening as doubling their distance from the source quarters their radiation dose[19]. Although not always feasible for intraoperative factors, optimum image intensifier positioning should be utilised where possible. Yet less than 50% of respondents could identify the radiation source with less than 34% knowing the optimum position for exposure reduction[20].

Compliance with lead aprons is quite high, with much lower compliance for thyroid guards, radio-protective eyewear, lead gloves and dosimetry[3-7, 21-23]. Compliance with eye visors is a major issue in infection protection with spectacles providing inadequate protection[15,18]. The inconsistent use of PPE presents an ongoing risk to staff with a demonstrated lack of awareness of same[14]. There is a paucity of research in this field with no intervention studies identified to date[3,23]. Visors were self-reported at 46.2%. 20.5% of participants "did not care" about the use of visors. These results were compounded by the poor risk awareness regarding exposure to HIV, HBV and HCV. The intervention was effective in improving the compliance of orthopaedic surgeons with thyroid shields.

Both the surgeons' and the radiographers' compliance improved significantly post-intervention. The radiographers were not part of the intervention group. This is likely coincidental because the lead for radiation education was present during an intervention talk highlighting radiographers' poor compliance. He likely addressed this issue separately with radiography staff. The levels of compliance recorded in this study reflect results of previous studies[4,5,21].

The surgeons' compliance with eye protection declined significantly post-intervention. These results were probably a random finding as more surgeons wore spectacles post-intervention and do not typically wear visors over glasses[14,15]. Additionally, the intervention was primarily focussed on radiation protection. This supports Singh et al.[14] findings demonstrating a perceived lack of necessity for eye protection.

Availability of thyroid shields is a commonly cited issue[3,6,22]. The mean availability of thyroid shields was less than one-third that of lead aprons throughout the study. 25.6% of questionnaire respondents cited unavailability as a reason for non-compliance. Logistic regression analysis demonstrated a 12.7% increased chance of a thyroid shield being used for each extra unit made available ($p=0.009$), a very implementable intervention**.** There were no specific storage spaces for thyroid shields in either centre, further increasing the likelihood of equipment loss. Providing specific storage space should improve availability. Attaching thyroid shields to lead aprons (a high compliance item) during manufacture would also help improve compliance.

Although there was a high number of observations (n=709), in two centres, staff numbers were limited.

CONCLUSION

This educational intervention improved the compliance of orthopaedic surgeons with PPE, specifically thyroid shields. Two primary factors need to be addressed to improve compliance with PPE; education and availability. The authors recommend that orthopaedic staff receive regular radiation training certification. Monitoring, training and regular compliance audits should be delegated to a centralised body to obviate the issue of monitoring certification in institutions with frequent staff turnover. Availability of PPE needs to be addressed locally at each institution. Lastly, it is recommended that thyroid shields be attached directly to lead aprons in future manufacturing to improve compliance and help resolve availability problems.

REFERENCES

1. Cheon BK, Kim CL, Kim KR, Kang MH, Lim JA, Woo NS, et al. Radiation safety: a focus on lead aprons and thyroid shields in interventional pain management. The Korean journal of pain. 2018;31(4):244-52.
2. Luntz M, Mozumder A, Tobias CA, Upton AC, Silverman J, Burton M. Radiation2021 [cited 2021 August]. Available from: https://www.britannica.com/science/radiation.
3. Nugent M, Carmody O, Dudeney S. Radiation safety knowledge and practices among Irish orthopaedic trainees. Irish Journal Of Medical Science. 2015;184(2):369-73.
4. Devalia KL, Guha A, Devadoss VG. The need to protect the thyroid gland during image intensifier use in orthopaedic procedures. Acta Orthopaedica Belgica. 2004;70(5):474-7.
5. Devalia KL, Peter VK, Madanur MA, Braithwaite IJ. Exposure of the thyroid to radiation during routine orthopaedic procedures. Acta Orthopaedica Belgica. 2006;72(5):615-20.

6. Cope MR, Shaw DL. The use and availability of thyroid shields in orthopaedic theatres: a telephone questionnaire of English hospitals. Annals Of The Royal College Of Surgeons Of England. 2002;84(3):193-5.
7. Jentzsch T, Pietsch CM, Stigler B, Ramseier LE, Seifert B, Werner CML. The compliance with and knowledge about radiation protection in operating room personnel: a cross-sectional study with a questionnaire. Archives of Orthopaedic & Trauma Surgery. 2015;135(9):1233-40.
8. Rehani MM, Vano E, Persliden J. Radiological protection in fluoroscopically guided procedures performed outside the imaging department International Commission on Radiological Protection; 2011 18/05/2011.
9. Environmental Health & Safety Centre Radiation Safety Division. Radiation Safety and ALARA2016 16/01/2018 [cited 2018. Available from: http://www.neuroradiologija.com/public/documents/ZastitaOdZracenja/Alara 1.pdf.
10. Munro L. Basics of Radiation Protection for Everyday Use. How to Achieve ALARA: Working Tips and Guidelines2004 13 October 2016. Available from: http://apps.who.int/medicinedocs/documents/s15961e/s15961e.pdf.
11. Bahari S, Morris S, Broe D, Taylor C, Lenehan B, McElwain J. Radiation exposure of the hands and thyroid gland during percutaneous wiring of wrist and hand procedures. Acta Orthopaedica Belgica. 2006;72(2):194-8.
12. Rashid MS, Aziz S, Haydar S, Fleming SS, Datta A. Intra-operative fluoroscopic radiation exposure in orthopaedic trauma theatre. European Journal of Orthopaedic Surgery & Traumatology 2018;28(1):9-14.
13. Alani A, Modi C, Almedghio S, Mackie I. The risks of splash injury when using power tools during orthopaedic surgery: a prospective study. Acta Orthopaedica Belgica. 2008;74(5):678-82.
14. Singh BI, Nurein H, Sinha S, Singh S, Housden P. Risk of conjunctival contamination in total joint arthroplasty. Journal of Hospital Infection. 2006;63(3):275-80.
15. Slevin B, Boyle L. HSE West Mid-Western Regional Hospitals, Standard Precautions Guideline, MGIP&C. Available from: http://www.hse.ie/eng/services/list/3/acutehospitals/hospitals/ulh/ipc/pdfs/1StandardPrecautions.pdf.
16. Kirby R. Operating Theatre Etiquette2014 [cited 2017 31st December]. Available from: http://www.uhnm.nhs.uk/SchoolOfMedicine/Documents/Operating Theatre Etiquette Poster Sep 14.pdf.
17. Health and Safety Executive. Advisory Committee on Dangerous Pathogens Protection against blood-borne infections in the workplace: HIV and Hepatitis, 2017 31-12-2017 [cited 2017 31st December]. Available from: http://www.hse.gov.uk/biosafety/diseases/bbv.pdf.
18. Centre for Disease Control. Guidance for the selection and use of personal protective equipment (PPE) in healthcare settings2016 31/12/2017. Available from: https://www.cdc.gov/hai/pdfs/ppe/PPEslides6-29-04.pdf.
19. OpenOregon Educational Resources. Inverse Square Law 2021. Available from: https://openoregon.pressbooks.pub/radsafety130/chapter/inverse-square-law/.
20. Panchbhavi VK. C-arm positioning: Medscape; 2014 [Available from: https://emedicine.medscape.com/article/1890603-technique - c2.
21. Jones DG, Stoddart J. Radiation use in the orthopaedic theatre: a prospective audit. The Australian and New Zealand Journal of Surgery. 1998;68(11):782-4.
22. Dewey P, Incoll I. Evaluation of thyroid shields for reduction of radiation exposure to orthopaedic surgeons. The Australian and New Zealand Journal of Surgery. 1998;68(9):635-6.
23. Chow R, Beaupre LA, Rudnisky CJ, Otto D, Clark M. Surgeons' perception of fluoroscopic radiation hazards to vision. American Journal Of Orthopedics (Belle Mead, NJ). 2013;42(11):505-10.