TECHNICAL REPORT

Light-weight lead aprons – light on weight, protection or labelling accuracy?*

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Abstract

X-ray transmission tests were performed on a Green-Lite (Infab Corporation) apron/vest combination, and compared to a number of other apron/vest combinations routinely used at Christchurch Hospital as well as a sheet of 0.5 mm lead. The materials were X-rayed using the primary beam of a Philips Optimus 50 X-ray machine over an energy range of 50-125 kVp. The entrance and exit doses were recorded and percentage transmission calculated for each kVp. The Green-Lite apron/vest (labelled as 0.5 mm lead at 85 kVp) relies on the overlap at the front to provide the nominal 0.5 mm protection for both the vest and the apron. It performed significantly worse than 0.5 mm of lead and other 0.5 mm lead equivalent apron/vest combinations and provided between 0.3 and 0.39 mm lead equivalent protection depending on the energy used. Vests from other manufacturers all achieved 0.5 mm lead equivalence for a *single* layer of vest material over the range of energies tested and so were comparable to 1.0 mm lead when doubled. Some aprons relied on a double layer of material to achieve the 0.5 mm lead equivalence (which was not always made clear on the label), while others stated their lead equivalence for a single layer. This resulted in some confusion among wearers of the aprons as to which apron was better.

Key words lead apron light-weight, Green-Lite

Introduction

Lead aprons are worn to protect staff from scattered X-rays during diagnostic and interventional X-ray procedures. In New Zealand, the Code of Safe Practice for the use of X-rays in Medical Diagnosis (NRL C5, 3.17) states that:

"(a) The fluoroscopist or any other person who is required to remain close to the patient during the x-ray procedure **shall** wear a leaded apron having a lead equivalence of not less than 0.25 mm and preferably of lead equivalence of 0.5 mm.

(b) Other persons who are required to remain in the room during fluoroscopy **shall** wear a leaded apron having lead equivalence of not less than 0.25 mm. "

These aprons are traditionally very heavy and can result in discomfort and back problems when worn for long periods. Aprons that contain no lead, or composites of lead, (e.g., lead, tungsten and barium) result in aprons that are up to 40% lighter in weight, and are becoming more widely used[1]. A popular design is to have a two-piece apron and vest combination, where the apron protects the waist down, and the vest protects the torso. This distributes the weight more evenly over the whole body, rather than placing it mostly on the shoulders as with a traditional long apron. The Green-Lite apron/vest combination (Infab Corporation) contains no lead, is 42% lighter than an all-lead apron and claims to offer 0.5mm lead equivalent protection at 85 kVp. Previous studies have shown considerable variation in the performance of lead aprons[2]. The Medical Physics and Bioengineering Department at Christchurch Hospital was approached by the Radiology Department (who were considering purchasing the garment) to test an example of the Green-Lite vest/apron combination and compare it to other similar garments in use at the hospital. Comparisons were also made to actual 0.5 mm lead sheeting and theoretical values of transmission through 0.5 mm lead.

Methods

The material being tested was placed in the primary beam of a Philips Optimus 50 X-ray machine as shown in Figure 1. A 15 cc ionisation chamber measured the entrance dose to the material and a 150 cc ionisation chamber measured the exit dose. The focus-table distance was 1m, the HVL of the system was 3.66 mm Al, and all exposures were 200 mA, 20ms. Measurements were initially made with no material in the beam to calibrate the two chambers,

**Presented at the Annual Conference of New Zealand Physics and Engineering in Medicine, Christchurch, New Zealand, 22-23 November 2004*
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Received: 24 March 2005; Accepted: 5 May 2005

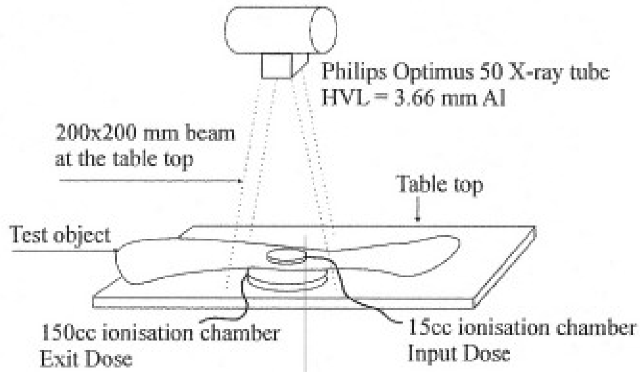

Figure 1. *Test setup for measuring the percentage of X-rays transmitted through a lead apron..*

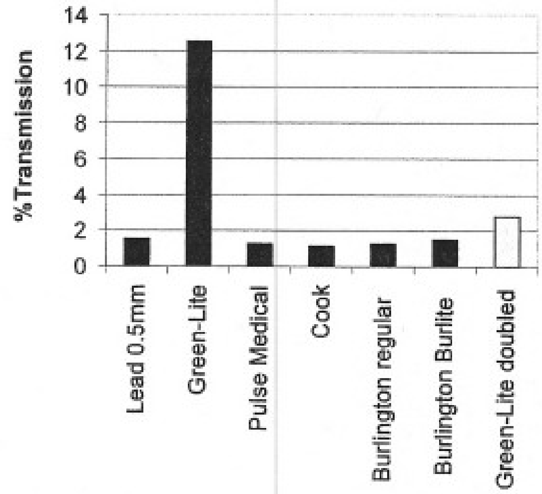

Figure 2. *X-ray transmission at 81 kVp through a single thickness of 0.5mm vest (double thickness of Green-Lite shown at the end for comparison).*

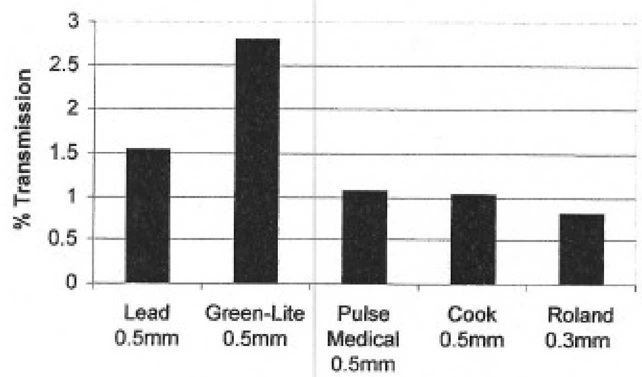

Figure 3. *X-ray transmission at 81 kVp through a double thickness of apron. Note the Roland 0.3 mm apron provides greater protection than the 0.5 mm aprons.*

and a correction factor of 0.8 was applied across all the x-ray energies tested (50-125 kVp). This corrects for geometric effects, calibration differences and shadowing of the exit chamber by the input chamber. Percent transmission was calculated as:

(Exit Dose / Input Dose) * 0.8 * 100%,

where 0.8 is the correction factor for the setup.

Theoretical values of transmission were calculated using the Specgen software, which uses the Birch and Marshall model[3] to calculate transmission through a material by a typical X-ray tube output.

Results

Vests

Results for a single layer of 0.5mm vests at 80 kVp are shown in Figure 2. The Green-Lite is the only vest tested that relies on an overlap to provide the nominal 0.5 mm Pb equivalent protection. A double thickness of the Green-Lite vest is shown at the end of the graph for comparison to the other vests which have 0.5mm for a single layer of vest, and so, when they are overlapped, provide 1.0mm lead equivalence.

Aprons

Results using a double thickness of apron are shown in Figure 3. The Green-Lite performed significantly worse than comparable aprons. The Roland 0.3 mm apron performed better than all the 0.5 mm wrap-around aprons as its lead equivalence is quoted for a single layer rather than a double layer. The Cook apron states on its label that the 0.5 mm Pb equivalent protection refers to the overlap region, but the Pulse Medical and Green-Lite aprons do not make this clear.

Energy dependence of the aprons

The transmission of X-rays through the aprons was checked over a range of X-ray energies from 50 to 125 kVp. The results are shown in Figure 4. The transmission through the Green-Lite apron is closest to the other aprons at 80-90 kVp (although significantly worse) and performs even more poorly than the other aprons at higher and lower energies. The calculated value was obtained using the Specgen software for 0.5 mm lead.

Discussion

Test setup

The test setup used (Figure 1) is not ideal, in that the 15cc ionisation chamber (measuring the input dose) shadows the 150cc ionisation chamber (measuring the exit dose). The calibration performed showed a consistent shadowing factor of 0.8 over all X-ray energies measured (50-125 kVp) which was corrected for in the results. The materials were also placed in close proximity to the chambers resulting in some measurement of scattered radiation from the material. Alternative methods were considered such as measuring the input dose once, then removing the 15 cc ionisation chamber and just measuring exit dose for all materials and X-ray energies tested. This would rely on the assumption that the X-ray tube output remained consistent, which was considered a likely source of error, and we considered that measuring input dose for

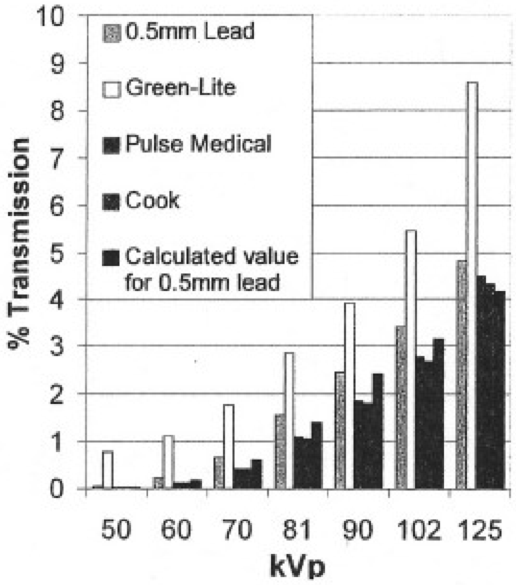

Figure 4. *X-ray transmission through a double thickness of 0.5 mm lead aprons and 0.5 mm lead over a range of diagnostic energies.*

every exposure was more reliable. Another variation considered was to place the 150cc ionisation chamber further away from the material and then correct for inverse square attenuation. This would reduce the scatter radiation measured, however at double layers of 0.5mm vest material the doses were very low, and so moving the chamber further away meant no reading could be obtained in some situations.

Because the setup was the same for all materials tested, the comparison between materials will give consistent results, although the absolute values of transmission may vary slightly due to the influence of some scatter radiation. The measured X-ray transmission through 0.5mm of actual lead was close to the predicted value using this set up, so the contribution from scatter to the value of transmission appears to have a minimal influence.

Labelling

The labelling of the aprons and vests was confusing. The Roland apron stated the lead equivalence for one thickness of material. The Cook apron stated (on a small and hard to read label) that 0.5 mm refers to the overlapped section at the front. The Green-Lite and Pulse Medical aprons just say 0.5 mm and do not specify what that applies to. This appears to breach Australian and New Zealand Standards[4] stating that both front and back sections should be labelled if different. This ambiguity has lead to radiographers believing the Roland apron (labelled 0.3 mm Pb) to be inferior to the others (labelled 0.5 mm Pb) whereas the opposite is true.

Performance

The Green-Lite vest/apron combination did not meet the 0.5mm lead equivalent protection that it claims to provide even at the stated 85 kVp. At its best energy response (80-90 kVp) it provides close to 0.39 mm lead equivalent protection with a double thickness of material. At higher energies it is more like 0.36 mm lead, and at lower energies (where much scatter radiation lies) is comparable to 0.3mm of lead. In addition to the Green-Lite material performing poorly, the design of the vest relying on a double layer to achieve 0.5 mm lead (rather than a single layer as in other vests) means that a single layer of the Green-Lite vest transmits nine times more X-rays than a single layer of other vest material.

Conclusions

The Green-Lite apron/vest performed poorly in comparison to other 0.5mm lead aprons and does not provide the 0.5mm lead equivalent protection that it claims on its label. The labelling of all aprons could be improved, particularly specifying the lead equivalence of both single and overlapped regions.

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