Full-body digital radiographic imaging of the injured child

Digital imaging offers many advantages over analogue radiography.

TANIA S DOUGLAS, ***BScEng, MS, PhD***

MRC/UCT Medical Imaging Research Unit, Department of Human Biology, University of Cape Town

Tania Douglas is Associate Professor of Biomedical Engineering at the University of Cape Town. She holds degrees in electrical/electronic engineering (University of Cape Town) and biomedical engineering (Vanderbilt and Strathclyde Universities) and completed a postdoctoral fellowship in image processing (Japan Broadcasting Corporation). She has recently become the Director of the MRC/UCT Medical Imaging Research Unit. Her research interests include computer-assisted diagnosis of tuberculosis and fetal alcohol syndrome, and paediatric applications of digital X-ray imaging.

RICHARD D PITCHER, ***MB ChB, FCRad (D) SA***

Division of Paediatric Radiology, Red Cross War Memorial Children's Hospital, School of Child and Adolescent Health, University of Cape Town

Richard Pitcher completed his radiology training in Cape Town and was, until recently, Head of the Division of Paediatric Radiology at Red Cross War Memorial Children's Hospital and the University of Cape Town. He has recently been appointed Associate Professor, Chief Specialist and Head of the Department of Radiodiagnosis at Stellenbosch University and Tygerberg Hospital. His main research interests have been the chest radiographic changes in HIV-infected children and digital imaging in paediatric trauma.

A B (SEBASTIAN) VAN AS, ***MBA, FCS (SA), PhD***

Head, Trauma Unit, Division of Paediatric Surgery, Red Cross War Memorial Children's Hospital, School of Child and Adolescent Health, University of Cape Town

Sebastian van As qualified as a medical doctor in the Netherlands. After working in rural Bophuthatswana, he specialised in general surgery at the University of Cape Town and sub-specialised in trauma. He holds a PhD in experimental liver transplantation. He heads the only dedicated trauma unit in Africa for children under the age of 13 years. In his capacities as National Director and later President of Childsafe South Africa, he has been active in a wide range of national and international prevention strategies for child injuries and child abuse.

Correspondence to: Tania Douglas (tania@ieee.org)

The benefits of digital over analogue radiography include reduced overall cost, particularly at high imaging volumes,[1] reduced examination time, increased patient throughput and a reduction in the number of repeat examinations,[2] and improved physician access to images during examinations as a result of timely production and electronic transfer.[3] These advantages of digital radiography can be exploited in the trauma setting, where diagnostic errors have been attributed primarily to inadequate radiography, with missed fractures occurring most frequently.[4]

The risks of ionising radiation remain an impediment to comprehensive imaging of the polytrauma patient, with each radiographic exposure increasing the cumulative dose of ionising radiation.[6] An increased risk of leukaemia and childhood cancer has been found with increased number of X-ray examinations.[7,8] A significant risk of breast cancer with increased mortality has been shown in scoliosis patients who had multiple diagnostic X-rays at a young age.[9] Limiting the frequency and dose of radiographic examinations while maximising the detection of injuries, i.e. limiting ionising radiation to 'as low as reasonably achievable', is a guiding principle in radiology,[10] particularly in the paediatric setting.

We present an overview of the use of the Lodox Statscan digital radiography system in the Trauma Unit at Red Cross War Memorial Children's Hospital, currently the only paediatric trauma unit in the world equipped with a full-body scanner. This imaging system enables comprehensive imaging at low dose, and is therefore well suited to paediatric trauma.

The tissues of children, in particular the thyroid gland, bone marrow, breast and lung parenchyma, are highly susceptible to the effects of radiation that predispose to malignancies in later life.

The Lodox Statscan digital imaging system

A Statscan (Lodox Systems, (Pty) Ltd., Sandton, South Africa) low-dose linear slot scanning full-body digital X-ray system was installed in the Trauma Unit at Red Cross War Memorial Children's Hospital in 2004 (Fig. 1).

A precursor to Statscan was employed for theft surveillance in the South African diamond mining industry. After recognition of its diagnostic potential, a clinical prototype was installed and evaluated in the Trauma Unit of Groote Schuur Hospital in Cape Town.[11,12] The quality of Statscan images was found to be comparable with that of conventional radiographs, and the unit was subsequently approved by the United States Food and Drug Administration (2002) and the European Union (2004). Statscan is used primarily

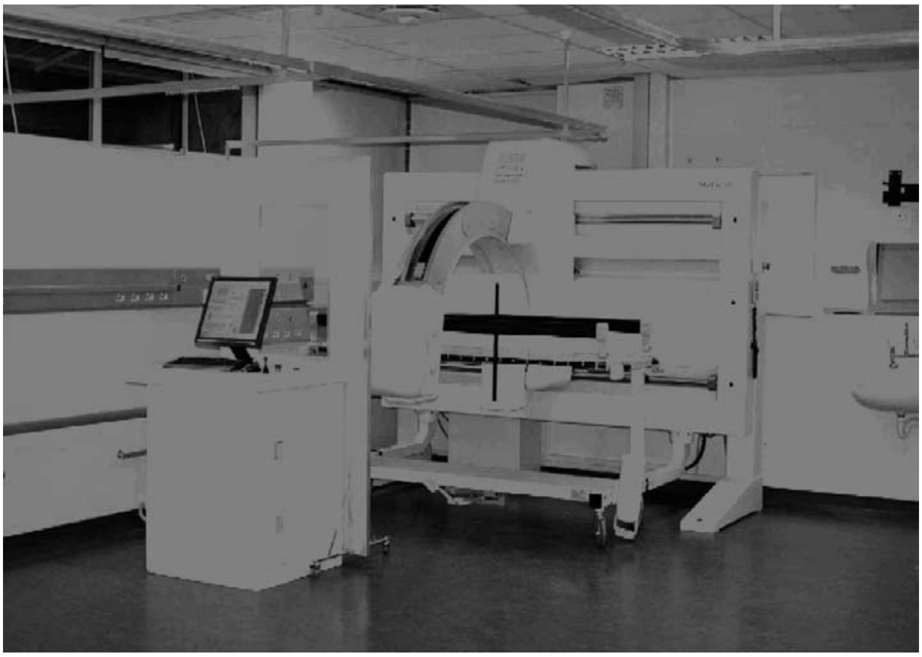

Fig. 1. The Statscan in the Trauma Unit at Red Cross War Memorial Children's Hospital.

for trauma imaging. It is currently the only FDA-approved device of its kind for trauma.[13]

A precursor to Statscan was employed for theft surveillance in the South African diamond mining industry.

X-ray source and detector banks are mounted on a C-arm that can be rotated around the patient. The C-arm's longitudinal motion allows a total scanned area of 1 800 × 680 mm; its rotation through 100° allows oblique and lateral projections. A custom-built height-adjustable trolley docks onto the C-arm, facilitating patient transport, imaging and access. An adult full-body radiograph ('bodygram') is produced in approximately 13 seconds; scanning time depends on patient height and is shorter in children.

Statscan produces less scattered radiation than conventional radiography systems, obviating the need for dedicated radiation protection and hence for patient transfer to a separate radiology department within the trauma unit. The Statscan system is located in the resuscitation room of the trauma unit, alongside a dedicated workstation where images are computed within 10 seconds of the scan and are immediately available to the clinician dealing with the trauma patient.

The effective radiation dose delivered by Statscan for the standard paediatric trauma imaging protocol is less than half that of an equivalent computed radiography (CR) protocol.[14] Adult effective doses are between 9% and 75% of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) doses for standard examinations.[15]

The slot-scanning technology is primarily responsible for the lower radiation dose of the Statscan system. An X-ray source projects a collimated fan-beam of X-ray energy through the patient onto a narrow slot detector, which is aligned with the source on the C-arm. The source and detector move in synchrony, building an image line by line, as the C-arm traverses the patient in the craniocaudal direction. Minimal scattered radiation is detected, resulting in high image quality with low radiation dose to the patient.

The effective radiation dose delivered by Statscan for the standard paediatric trauma imaging protocol is less than half that of an equivalent computed radiography (CR) protocol.

Overview of Statscan use in paediatric trauma

A pilot evaluation of the role of Statscan in paediatric polytrauma showed the machine to be effective for triage evaluation, producing image quality comparable with that of a standard computed radiography (CR) system.[16] CR replaces the film used in conventional screen-film radiography with an imaging plate which is scanned to produce a digital image; it is not fully digital, but offers some of the advantages of digital radiography.

Multiple fractures were demonstrated in 40% of patients with positive imaging findings; femoral fractures were the most common injury.

The polytrauma imaging protocol at Red Cross War Memorial Children's Hospital was modified in response to the favourable performance of Statscan:[17] the standard CR polytrauma series comprising (*i*) lateral cervical spine, (*ii*) supine chest, (*iii*) anteroposterior (AP) pelvis, and (*iv*) localised AP and lateral projections of any additional area of clinical suspicion for bony injury, was superseded by a new protocol including (*i*) Statscan AP bodygram, (*ii*) Statscan lateral cervical spine, and (*iii*) localised lateral views of any area of clinical or radiological suspicion for bony injury. The new Statscan protocol was, on average, 13% faster than the CR protocol.[16] CR remains the modality of choice for focal trauma imaging.

A review of Statscan use during the first 2 years of the new protocol revealed that approximately 5% of patients (867, median age 72 months, 64% male) treated at the trauma unit had sustained polytrauma and qualified for Statscan imaging.[17] Motor vehicle accidents (MVAs) were the most common cause of polytrauma, accounting for 73.5% of imaging examinations; 50% of patients were pedestrians. Statscan yielded positive diagnostic findings in 40% of cases, with the highest diagnostic yield in MVA cyclists (50%). Multiple fractures were demonstrated in 40% of patients with positive imaging findings. Femoral fractures were the most common injury.

More than 13% of diagnostic errors in emergency departments have been attributed to failure to perform appropriate radiography,[4] as a result of reliance on standard imaging protocols and clinical signs as indicators for focal imaging. Inadequate assessment may contribute to up to 30% of early deaths in children with polytrauma.[18] Statscan full-body radiography has enabled the early detection of fractures in paediatric trauma patients in the absence of associated clinical signs.[19] Full-body imaging can assist in the diagnosis of multiple injuries, which are often assessed with difficulty, particularly in the presence of an associated head injury.[20]

Inadequate assessment may contribute to up to 30% of early deaths in children with polytrauma.

The location of the Statscan in the trauma unit enables the patient to remain in the resuscitation room; imaging and resuscitation can be performed concurrently. Transportation of a patient suffering polytrauma to the radiology suite is not only time consuming and labour intensive. It also carries significant risks for complications, with adverse effects to the patient, such as dislodging of endotracheal and nasogastric tubes, drips, intercostal drains and catheters.

Multiple casualties strain the resources of emergency units, lead to increased length of stay and can have an adverse effect on patient outcome. Variation from the norm in response to the demands of a multiple casualty incident, particularly during initial assessment and resuscitation, has been associated with preventable morbidity and mortality.[21] Full-body digital radiography in adults, when compared with conventional radiography, has been found to reduce X-ray imaging time by 3, 21, and 42 minutes for ambulatory, stretcher-borne, and resuscitation trauma patients, respectively.[12] Another adult study showed that acquisition of full-body AP and lateral images could be completed in 6.5 minutes, compared with 25.7 minutes for multiple conventional X-rays taken for the same purpose.[22] The Statscan trauma protocol reduces image acquisition time in the emergency unit, especially when multiple patients present simultaneously, and has the potential to improve emergency department efficiency in dealing with multiple casualty incidents.[23]

Figs 2 and 3 show examples of Statscan images.

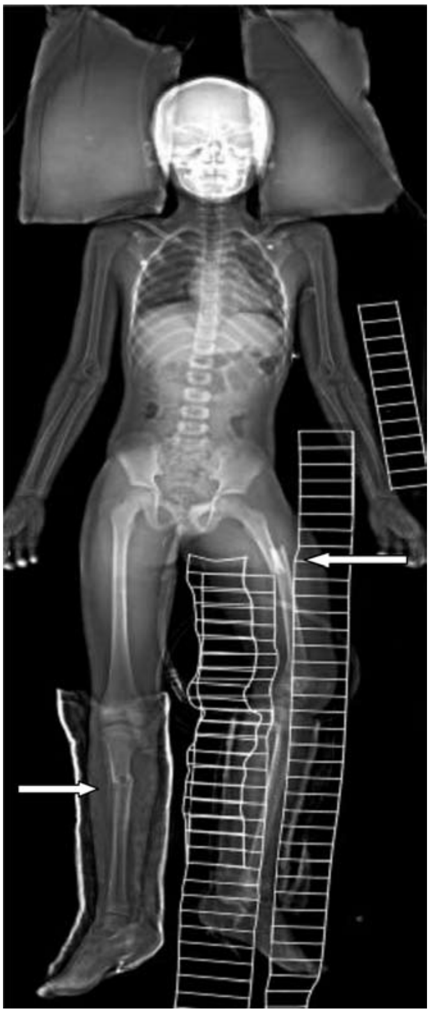

Fig. 2. Typical example of the full-body image produced by the Statscan. Injuries revealed by the image are a fractured right femur and fractures of the left tibia and fibula (arrows). Note the sandbags stabilising the head and neck and the various fracture splints with the metal skeleton.

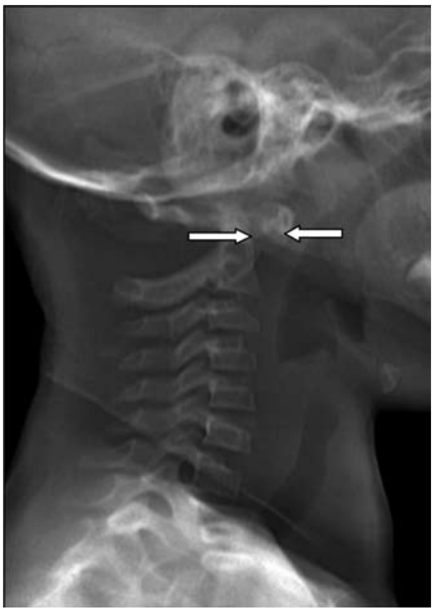

Fig. 3. Lateral cervical spine image produced by the Statscan, demonstrating a widened interval between the atlas and the dens.

Conclusion

Full-body radiographic imaging in the paediatric trauma environment has value in terms of diagnostic yield and efficiency. Capturing the entire body using conventional radiography would require multiple images at high cumulative radiation dose and increased scanning time. The low-dose advantage of the Statscan machine in combination with its full-body imaging capability and the speed at which images are available for viewing, make it particularly attractive in paediatric trauma imaging.

References

1. Dalla Palma L, Grisi G, Cuttin R, Rimondini A. Digital vs conventional radiography: cost and revenue analysis. *Eur Radiol* 1999; 9: 1682-1692.
2. Wideman C, Gallet J. Analog to digital workflow improvement: A quantitative study. *J Digit Imaging* 2006; 19: 29-34.
3. Ng KH, Rehani MM. X ray imaging goes digital – Digital imaging brings benefits but also demands changes in ways of working. *BMJ* 2006; 333(7572): 765-766.
4. Guly HR. Diagnostic errors in an accident and emergency department. *Emerg Med J* 2001; 18(4): 263-269.
5. Ron E. Ionizing radiation and cancer risk: evidence from epidemiology. *Pediatr Radiol* 2002; 32(4): 232-237.
6. ICRP. 1990 Recommendations of the International Commission of Radiological Protection. *Ann ICRP* 1991; 21: 1-201.
7. Infante-Rivard C, Mathonnet G, Sinnett D. Risk of childhood leukemia associated with diagnostic irradiation and polymorphisms in DNA repair genes. *Environ Health Perspect* 2000; 108(6): 495-498.
8. Shu XO, Jin F, Linet MS, *et al.* Diagnostic x-ray and ultrasound exposure and risk of childhood-cancer. *Br J Cancer* 1994; 70(3): 531-536.
9 Doody MM, Lonstein JE, Stovall M, Hacker DG, Luckyanov N, Land CE. Breast cancer mortality after diagnostic radiography – Findings from the US Scoliosis Cohort Study. *Spine* 2000; 25(16): 2052-2063.
10. Willis CE, Slovis TL. The ALARA concept in pediatric CR and DR: dose reduction in pediatric radiographic exams – A white paper conference Executive Summary. *Pediatr Radiol* 2004; 34(Suppl 3): S162-S164.
11. Beningfield SJ, Potgieter JH, Bautz P, *et al.* Evaluation of a new type of direct digital radiography machine. *S Afr Med J* 1999; 89(11): 1182-1188.
12. Beningfield SJ, Potgieter H, Nicol A, *et al.* Report on a new type of trauma full-body digital X-ray machine. *Emerg Radiol* 2003; 10: 23-29.
13. Evangelopoulos DS, Deyle S, Zimmermann H, Exadaktylos AK. Personal experience with whole-body, low-dosage, digital X-ray scanning (LODOX-Statscan) in trauma. *Scand J Trauma Resusc Emerg Med* 2009; 17(1): 19.
14. Maree GJ, Irving BJ, Hering ER. Paediatric dose measurement in a full-body digital radiography unit. *Pediatr Radiol* 2007; 37(10): 990-997.

15. Irving BJ, Maree GJ, Hering ER, Douglas TS. Radiation dose from a linear slit scanning x-ray machine with full-body imaging capabilities. *Radiat Prot Dosimetry* 2008; 130(4): 482-489.
16. Pitcher RD, van As AB, Sanders V, *et al.* A pilot study evaluating the "STATSCAN" digital X-ray machine in paediatric polytrauma. *Emerg Radiol* 2008; 15: 35-42.
17. Pitcher RD, Wilde JCH, Douglas TS, van As AB. The use of the Statscan digital X-ray unit in paediatric polytrauma. *Pediatr Radiol* 2009; 39(5):433-437.
18. Browne GJ, Cocks AJ, McCaskill ME. Current trends in the management of major pediatric trauma. *Pediatr Emerg Med* 2001; 13: 418-425.
19. Douglas TS, Sanders V, Pitcher R, van As AB. Early detection of fractures with low-dose digital x-ray images in a pediatric trauma unit. *Journal of Trauma-Injury Infection and Critical Care* 2008; 65: E4-E7.
20. van As AB, Douglas TS, Kilborn T, Pitcher R, Rode H. Multiple injuries diagnosed using full-body digital x-ray. *J Pediatr Surg* 2006; 41(7): e25-e28.
21. Al Naami MY, Al Faki AA, Sadik AA. Quality improvement data analysis of a mass casualty event. *Injury-International Journal of the Care of the Injured* 2003; 34: 857-861.
22. Exadaktylos AK, Benneker LM, Jeger V, *et al.* Total-body digital X-ray in trauma – An experience report on the first operational full body scanner in Europe and its possible role in ATLS. *Injury-International Journal of the Care of the Injured* 2008; 39(5): 525-529.
23. Koning L, Douglas TS, Pitcher R, van As AB. Short emergency department length of stay attributed to full-body digital radiography – a review of 3 paediatric cases. *S Afr Med J* 2006; 96(7): 613-614.

In a nutshell

- Total body scanning is an ideal imaging mode for injured children presenting with polytrauma.
- The total body scan can be performed faster and with less radiation compared with conventional radiographic methodologies.
- Total body scanning can also be utilised for triage evaluation.
- The scanner should ideally be located in the resuscitation room.
- Due to the slot-scanning technology, there is less scattered radiation and imaging of the vertebral column is improved.

Single Suture

No pill to prevent ageing yet

Two major drug companies, Pfizer and GlaxoSmithKline, are nowhere close to developing a pill that can halt the march of old age. Drugs that may treat the disease by interfering with the biochemistry and physiology of ageing are being tested, but the latest research suggests that they may not work as first thought.

Compounds in the drugs include resveratrol, present in red wine, which is thought to prevent the cellular damage that underlies ageing. There are also several chemicals being tested that are intended to mimic resveratrol's effects by activating a protein called SIRT1, which is implicated in ageing. Some researchers think that these drugs increase this protein's activity, but there may be errors in the research.

GlaxoSmithKline is hoping that resveratrol and similar drugs will treat age-related disorders such as type 2 diabetes and cancer. However, a laboratory test designed to measure how much drug activity boosts the activity of SIRT1 may be providing false positives.

Pfizer, in their own search for anti-ageing drugs, tested resveratrol and three other anti-ageing compounds using more sensitive methods and found that none of the compounds work as expected. And, the drugs also seemed to have unintended side-effects that could make them less useful in humans. Another team also concluded that resveratrol doesn't activate SIRT1.

The controversy continues.

Chemical Biology & Drug Design, DOI:10.1111/j.1747-0285.2009.00901.x

The Journal of Biological Chemistry, DOI:10.1074/jbc.m109.088682