Journal of Radiotherapy in Practice

Journal of Radiotherapy in Practice (2013)
12, 80–87

doi:10.1017//S1460396912000192

Technical Note

Impact of software changes: Transit dose and source position accuracy of the Eckert & Ziegler BEBIG GmbH MultiSource® high dose rate (HDR) brachytherapy treatment unit

A. Palmer[1,2]

[1]*Radiotherapy Physics, Medical Physics Department, Portsmouth Hospitals NHS Trust, United Kingdom,*
[2]*Department of Physics, Faculty of Engineering and Physical Science, University of Surrey, United Kingdom*

(Received 28 October 2011; revised 26 January 2012; accepted 08 February 2012; first published online 2 August 2012)

Abstract

Purpose: Medical device performance checks are essential following changes to control system software. This work investigates the effects of new software on the performance of a high dose rate (HDR) brachytherapy treatment unit.

Methods and Materials: A performance assessment was undertaken of the Eckert & Ziegler BEBIG GmbH MultiSource® HDR treatment unit following software upgrade. Video recordings of source transits were used to calculate transit doses, and autoradiography used to measure source dwell positions. Results were compared to a previous study.[1]

Results: All results showed improved performance with the new compared to old control software. Optimal source movement profiles were observed with maximum transit speeds of 63 (+/−4) mm s^{-1} between dwells of 5.0 mm separation. The maximum error in transit dose correction with the new software was 2.5 % at 10.0 mm perpendicular from the source axis, compared to 5.6 % previously. The new software eliminated a causal relationship between curvature of the source transfer tubes and dwell position uncertainty.

Conclusions: This work demonstrates the need for comprehensive medical device system checks following software changes. Technical improvements in HDR device performance have been achieved with the new software; reducing transit doses, improving transit dose correction, and improving source positioning accuracy.

Keywords

HDR high dose rate; QC; transit dose; dwell position; accuracy; software

INTRODUCTION

The treatment of cancer using high dose rate (HDR) brachytherapy requires accurate and

Correspondence to: Antony Palmer, Head of Radiotherapy Physics, Medical Physics Department (Radiotherapy), F-Level, Queen Alexandra Hospital, Portsmouth Hospitals NHS Trust, Portsmouth, United Kingdom. E-mail: antony.palmer@porthosp.nhs.uk

careful planning and delivery. The ability of a HDR unit to accurately implement a series of planned source dwells is critical to the quality of the resulting treatment. The accuracy of delivered doses is particularly dependent on source positioning due to the short distances between target and source; steep dose gradients and large inverse-square law effects of any geographic errors.

HDR treatment planning systems do not normally make any correction for the transit dose which results from movement of the source between dwells, assuming that these can safely be ignored due to the low actual transit time and dose, and if significant, that the HDR unit will itself make appropriate corrections to the planned dwell time. The equipment user is often unaware of the magnitude of the transit dose and corrections that are automatically made to dwell time. The practice and validity of not considering transit doses in treatment calculations must be verified for each manufacturer's HDR unit, relating to its particular source velocity, resulting transit dose, and the accuracy of any transit dose corrections that are made.

In comparison to external beam radiotherapy, the physical process by which HDR brachytherapy treatment units deliver treatment is simple. However, this does not mean the quality control task is without complexity, and this must be undertaken comprehensively to mitigate risk of treatment error. This is especially true when control system software is changed, which may affect the performance of equipment. Positioning accuracy and transit dose corrections, as discussed above, could be affected. An appropriate set of checks must be devised which adequately test expected changes, based on software 'release notes' from the manufacture, but also gives reassurance of the absence of any unexpected performance alterations. Several recent publications have provided updated guidance on quality control of HDR brachytherapy delivery, including transit dose assessments,[2,3,4] measurement methods,[5] and general quality control recommendations.[6] This literature should be consulted when determining the appropriate measurements for particular HDR systems and the nature of the software change.

Previous HDR system performance evaluations[1,7,8] have shown that there can be appreciable source control and dosimetric differences between different models of HDR systems. However, there are no publications on the potential performance differences between software versions of the same HDR unit, which is addressed in this work. Analogous work for software changes in external beam radiotherapy treatment planning systems is already embedded into routine clinical physics practice, where understanding and characterisation of any changes is required before clinical use resumes.[e.g. 9]

In a previous study, we documented the comprehensive commissioning process for HDR treatment units and specifically results for the Eckert and Ziegler BEBIG GmbH (further termed 'EZ BEBIG') Multisource® HDR treatment unit.[1] The work concluded with three suggestions for technical improvements to (a) the compensation calculation for transit dose, (b) the source transit movement profile to the first dwell point, and (c) the effect of curvature of source transfer tubes on source position accuracy. Positioning errors of the source, of up to 1.0 mm for slight bends, 2.0 mm for moderate bends and 5.0 mm for extreme curvature (depending on applicators and transfer tube used) were reported in the study. EZ BEBIG were quick to respond and develop improved control system software addressing each of these technical issues. The aim of this study is to reassess the performance of the treatment unit in these specific areas, updating the previous published work, and illustrate in general the need for comprehensive checks following software changes to medical devices, specifically in this case HDR treatment units.

METHODS AND MATERIALS

An EZ BEBIG MultiSource® HDR treatment unit with software version 7.4.1, firmware

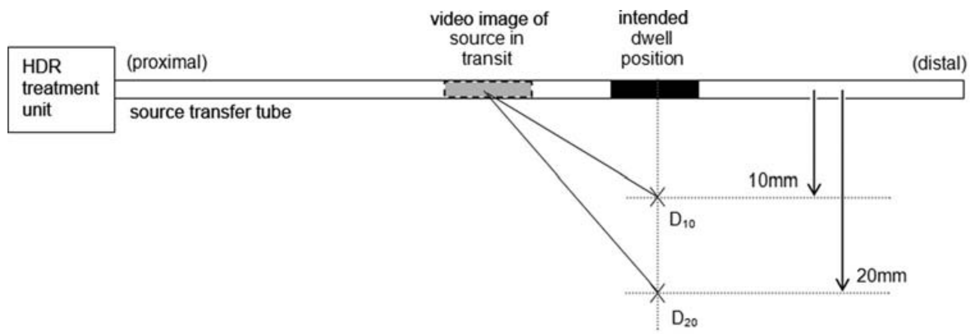

Figure 1. Transit dose calculation points, D_{10} and D_{20}, at 10 mm and 20 mm respectively, perpendicular distance from the centre of the intended dwell position.

version 4.14.1, was used throughout this study. The results of all analyses were compared to data obtained with the previous HDR control software, version 7.4.0, firmware version 4. All results are based on use of the HDR unit with a ^{192}Ir source, model Ir2.A85–2.[1]

Video measurement of source transit

A high definition video camera (Panasonic HDC-SD10) was used to image a catheter during a treatment prescription consisting of three dwells at 10.0, 15.0 and 20.0 mm. The centre of the source was identified visually in each video frame, at a resolution of 25 frames per second, and the position recorded against a ruler also located within the video image. This data set was used to evaluate the location of the source as a function of time between dwell positions and to calculate the speed of source movement by the simple division of displacement and elapsed time.

Transit dose calculation and system correction

Using the above data set, the source position was recorded at 1/25 s intervals in the approach to the first dwell position, between dwells, and from the last dwell back to the HDR unit. An approximation of the transit dose was calculated by the summation of the dose delivered by the source considered to be stationary for 1/25 s at each of the imaged positions, using published dose-rate distribution data.[10] The transit dose was calculated separately for the movement of the source to and from the dwell position, and evaluated at two interest points, D_{10} and D_{20}, located at 10 mm and 20 mm respectively from the centre of the dwell position, perpendicular to the source movement axis, shown in Figure 1.

The EZ BEBIG Multisource® makes corrections for transit doses by reducing the actual dwell time for each dwell position using the following algorithm (Spiller 2011):

$$pDT = DT - T_{r(to\ dwell)} - T_{r(from\ dwell)}$$
$$T_r = cd + 100$$

where pDT is the performed dwell time (ms), DT is the planned dwell time (ms), T_r is the time reduction applied to the dwell position for each transit (ms), d is the distance between dwell positions (mm), and c is a constant which equals 3 for dwell separations of less than or equal to 100 mm, and equals 2 for dwell separations of greater than 100 mm. T_r for the first and last dwell positions is fixed at 450 ms. The fixed time reduction applied to the first and last dwells was introduced with the new software, all other algorithm parameters being consistent with the previous software version.

https://doi.org/10.1017/S1460396912000192 Published online by Cambridge University Press

The transit dose correction implemented by the EZ BEBIG Multisource® was evaluated for the specific treatment situation detailed above, and the 'equivalent dose reduction' resulting from this dwell time reduction was compared to the calculated transit dose, using the video analysis data.

Autoradiography of dwell position accuracy with transfer tube curvature

The actual source dwell positions were measured and compared to planned dwell positions for a range of applicators and transfer tubes, in terms of absolute accuracy and reproducibility. It had been reported in previous work[1] that the actual dwell position may be affected by curvature of the transfer tube between the HDR unit and the applicator. Therefore measurements were made with a curvature induced in the transfer tube by displacing the distal end of the tube by distances of 10.0, 30.0 and 90.0 cm, while maintaining a stationary proximal end at the HDR unit. The 90.0 cm displacement is included as an extreme 'physically limiting' case and not an expected realistic clinical situation.

X-ray film autoradiography (Kodak EDR2 Ready Pack film, 1 s dwells) was used to assess source positional accuracy for a treatment prescription consisting of three dwells at 5.0, 35.0 and 105.0 mm, for straight and curved transfer tubes with a range of applicators.

RESULTS AND DISCUSSION

Source movement profiles

Figure 2 shows the position of the source as a function of time on approach to the first dwell, at 1/25 s resolution imaged with a video camera, when the EZ BEBIG MultiSource® system was operated with (a) the new control software, and (b) the old control software. The new software moves the source directly to the first dwell position, rather than intentionally driving beyond the first position and pausing as controlled by the old software. The intentional pause was implemented in the previous software to enable any slack or 'snaking' of the cable to be released prior to fine final positioning. The new software implements an empirical correction (applicator and transfer tube specific) to account for this and achieves the same final positional accuracy. The maximum recorded source transit speed was 400 (+/− 20) mm s^{-1} in both data sets.

The maximum speed achieved between dwells of 5.0 mm separation was 63 (+/− 4) mm s^{-1} with the new control software, which is consistent with measurements made with the old software at 62 (+/− 4) mm s^{-1}[1] Figure 3 shows the movement profile between 10.0 and 15.0 mm dwell positions, which is similar to that between 15.0 and 20.0 mm dwells. Movement between all dwells appeared smooth with equal phases of acceleration and deceleration, no 'overshoot' in dwell positioning, nor any fine corrections required to achieve the final dwell position.

The largest positional uncertainty from the video analysis technique was +/− 2 mm at maximum source speed, which reduced as the source slowed; this being estimated from the extent of blurring in the video frames. The final intended source dwell position was always achieved within +/− 0.5 mm. The uncertainty in speed is quoted as the quadrature sum of positional and time uncertainty.

Transit dose and corrections

Table 1 presents transit doses calculated from video analysis of source movement compared to the equivalent dose reduction implemented from the EZ BEBIG MultiSource® system correction algorithm, at D_{10} and D_{20} (10.0 and 20.0 mm from the centre of the dwell position perpendicular to the source movement axis), for the new and old control software. The magnitude of the actual transit dose at the first dwell is reduced with the new software due to the absence of the preceding 'pause' in approaching the first dwell (see Figure 1). All other actual transit doses are consistent within experimental uncertainty between the two software versions.

https://doi.org/10.1017/S1460396912000192 Published online by Cambridge University Press

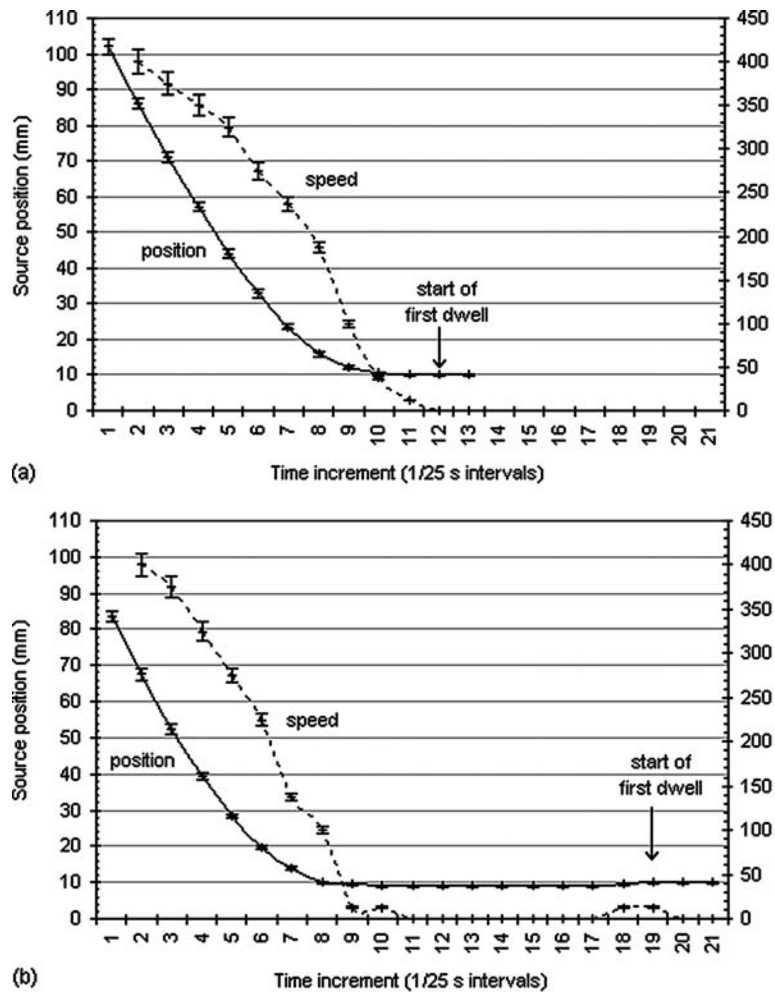

Figure 2. Position and speed of source during transit from the EZ BEBIG Multisource® on approach to the first dwell position at 10.0 mm, with (a) the new control software and (b) the old control software.

At both D_{10} and D_{20} the applied correction for a dwell within a series (15.0 mm dwell point in this example) is consistent between the two software versions, and is equivalent to the actual transit dose calculated from the video analysis. The majority of dwells in a clinical treatment will be mid-series dwells; hence this result is most significant.

The new control software applies a larger transit dose correction for the first dwell compared to the old software, 0.45 s compared to 0.15 s, and this is in closer agreement to the actual transit dose in the cases considered; At D_{10} the actual transit dose is 2.94 (+/− 0.05) cGy for the new software and 7.45 (+/− 0.05) cGy for the old software, resulting in transit dose correction errors of -2.6 % and 5.6 % respectively. At D_{20} the actual transit dose is 0.91 (+/− 0.05) cGy and 3.00 (+/− 0.05) cGy for the new and old software, resulting in errors of 0.5 % and 2.5 % respectively.

The magnitude of the actual transit dose will reduce as the source decays since the transit time is unchanged, but the dose rate from the source will decrease. At D_{20}, for a dwell point within a series of 5.0 mm separation dwells, as above, there will be a software time correction (both new and old versions) resulting in an equivalent dose reduction of 0.72 (+/− 0.02) cGy. For a new Ir-192 source the actual transit dose in this case is 0.73 (+/− 0.05) cGy. However, when the source has decayed to the end of its normal clinical use period, the actual transit dose is reduced to 0.31 cGy at 3 months or 0.23 cGy at 4 months, leading to a small overcorrection by the software.

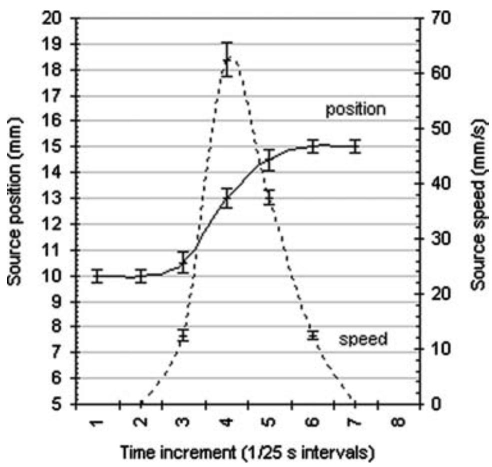

Figure 3. Position and speed of source during transit from first to second dwell positions, from a series of three dwells at 10.0, 15.0 and 20.0 mm, with new control software.

Dwell position accuracy with transfer tube curvature

Figure 4 compares the affect of source transfer tube curvature on actual dwell positions between the old and new EZ BEBIG MultiSource® control system software. There is a clear and significant improvement in accuracy of the actual compared to intended dwell positions with the new software. In all but the extreme curvature case (90 cm displacement), the dwells are accurate within 1.0 (+/− 0.5) mm with the new software, compared to typical errors of 3.0 (+/− 0.5) mm at 100 mm displacement and up to 6.5 (+/− 0.5) mm at 300 mm displacement, with the oldsoftware.

Previous work by Palmer et al (2009)[1] has suggested that dwell position errors due to transfer tube curvature are the result of the drive cable taking the outer radius of the source trans-

Table 1. *Comparison of actual calculated transit dose and EZ BEBIG Multisource® compensated transit dose, for each dwell position in a series of three dwells, at 10.0, 15.0 and 20.0 mm, evaluated at D_{10} and D_{20} (10.0 and 20.0 mm from the centre of the dwell position perpendicular to the source movement axis), for the apparent activity of a new Ir-192 source. The data is presented for both the new and old control system software.*

Dwell point	Treatment unit calculated dwell time reduction (s)	Equivalent dose reduction implemented (cGy) (+/− 0.02)	Actual transit dose (cGy) (+/−0.05)	Transit dose error 'actual − corrected' dose (cGy) (+/−0.1)
D_{10}, **New** control software				
10.0 mm (first)	0.45	5.49	2.94	−2.6
15.0 mm	0.23	2.81	2.66	−0.2
20.0 mm (last)	0.45	5.49	2.65	−2.8
D_{10}, **Old** control software				
10.0 mm (first)	0.15	1.83	7.45	5.6
15.0 mm	0.23	2.81	2.62	−0.2
20.0 mm (last)	0.15	1.83	2.72	0.9
D_{20}, **New** control software				
10.0 mm (first)	0.45	1.41	0.91	−0.5
15.0 mm	0.23	0.72	0.73	0.0
20.0 mm (last)	0.45	1.41	0.90	−0.5
D_{20}, **Old** control software				
10.0 mm (first)	0.15	0.47	3.00	2.5
15.0 mm	0.23	0.72	0.73	0.0
20.0 mm (last)	0.15	0.47	0.85	0.4

https://doi.org/10.1017/S1460396912000192 Published online by Cambridge University Press

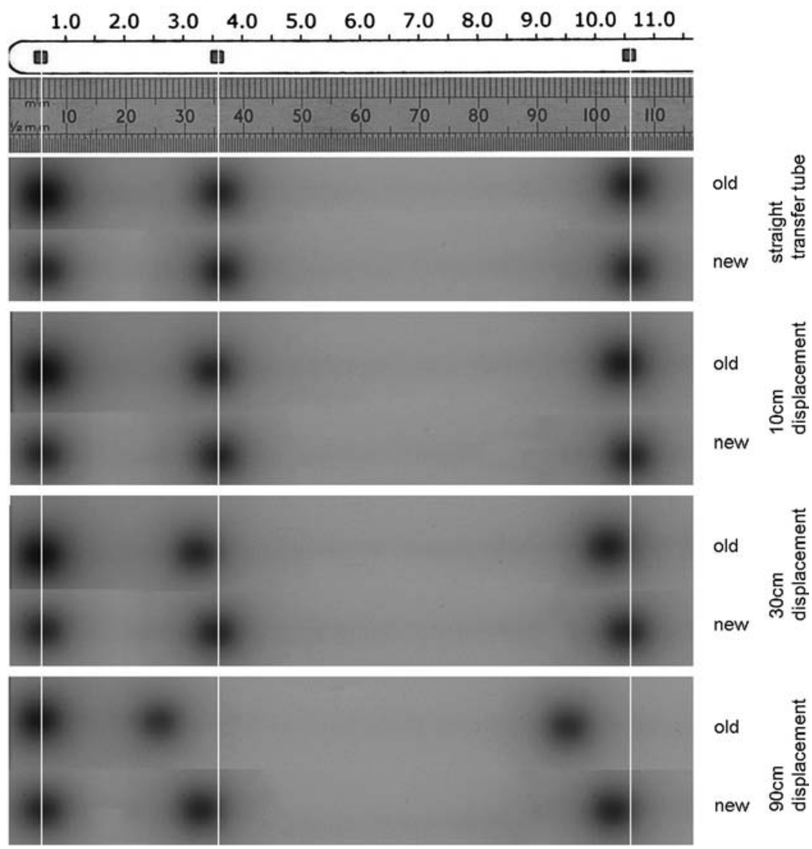

Figure 4. Autoradiographs of actual source dwell positions compared to planned positions (vertical lines) as a function of curvature of the transfer tube, for the 1400 universal applicator (140 cm length), both for the previous EZ BEBIG Multisource® control system software, 'old', and the latest software, 'new'. The autoradiographs are for a straight transfer tube and for bends induced by displacements of the distal end by 10, 30 and 90 cm toward the treatment unit.

fer tube during the outward drive motion, as well as potential 'snaking', and then taking up this 'slack' during distal-to-proximal stepping of the source during the initial few dwells; the drive cable taking the internal radius on return to the EZ BEBIG MultiSource® unit. The new control software has mitigated this error by using empiric applicator factors to account for resistance and moving properties of the source cable, for each applicator and transfer tube combination.[11]

An unintended dose enhancement at the first dwell position can be seen on the autoradiograph with the old software, which is no longer present with the new software, Figure 3. This is due to the elimination of the transit pause prior to the first dwell.

SUMMARY AND CONCLUSIONS

The results of this work demonstrate how a change in equipment software can significantly affect the performance of a medical device. The need for robust quality control checks after software changes is therefore reinforced, either to confirm improvements or to detect any unexpected changes in performance.

In the HDR brachytherapy treatment unit case presented, the accuracy of dwell positions with transfer tube curvature, transit dose at the first dwell, and transit dose corrections have been markedly improved with the latest internal operating software. The data shows that the EZ BEBIG Multisource® HDR treatment unit is capable of high quality brachytherapy treatment delivery and that recently suggested technical improvements[1] have been fully implemented in the new control system software.

ACKNOWLEDGMENTS

The author wishes to acknowledge the contribution of Orla Hayman and Eckert & Ziegler BEBIG GmbH (especially Antonius Spiller) for scientific review and verification of this work and also Bongile Mzenda for contributions to prior enabling work. The author also thanks Professor David Bradley and Professor Andy Nisbet, University of Surrey, for scientific supervision

References

1. Palmer A, Mzenda B. Performance assessment of the BEBIG Multisource® high dose rate brachytherapy treatment unit. Phys Med Biol 2009; 54:7417–7434.
2. Menon GV, Carlone MC, Sloboda RS. Transit dose contributions to intracavitary and interstitial PDR brachytherapy treatments. Phys Med Biol 2008; 53:3447–3462.
3. Minamisawa RA, Rubo RA, Seraide RM, Rocha JRO and Almeida A. Direct measurement of instantaneous source speed for a HDR brachytherapy unit using an optical fiber based detector. Med Phys 2010; 37:5407–5411.
4. Yewondwossen M. Measurement of transit dose of an Ir-192 HDR brachytherapy stepping source using a 2D-array of ion chambers. Med Phys 2011; 38:3573.
5. Rickey DW, Sasaki D, Bews J. A quality assurance tool for high-dose-rate brachytherapy. Med Phys 2010; 37:2525–2532.
6. Pawlicki T, Dunscombe PB, Mundt AJ, Scalliet P. Quality and safety in radiotherapy. Boca Raton, Taylor & Francis 2011. ISBN: 978–1-4398–0436-0.
7. McDermott PN, Somnay AR, Alecu R. Acceptance testing and commissioning of a new model HDR afterloader. Radiother Oncol 1996; 39:S25.
8. Wallace AB. Acceptance testing, commissioning and quality assurance for a 370GBq Ir-192 HDR brachytherapy afterloader. Australas Phys Eng Sci Med 1997; 20:112–116.
9. McGarry C, O'Toole M, Cosgrove V. Characterising intensity-modulated radiation therapy (IMRT) software following upgrades in a commercial treatment planning system. Journal of Radiotherapy in Practice 2010; 9:209–221.
10. Granero D, Perez-Calatayud J. Study of a new Co-60 source used in brachytherapy. Med Phys 2007; 34:3485–3488.
11. Spiller A; on behalf of Eckert & Ziegler GmbH. Personal communication with the author via email, July 2011.

https://doi.org/10.1017/S1460396912000192 Published online by Cambridge University Press