International Journal of Technology Assessment in Health Care, **21:4** (2005), 487–491.

Predicting the impact of new health technologies on average length of stay: Development of a prediction framework

Sue Simpson, Claire Packer, Andrew Stevens, James Raftery
The University of Birmingham

Objectives: The aim of this study was to develop a framework to predict the impact of new health technologies on average length of hospital stay.
Methods: A literature search of EMBASE, MEDLINE, Web of Science, and the Health Management Information Consortium databases was conducted to identify papers that discuss the impact of new technology on length of stay or report the impact with a proposed mechanism of impact of specific technologies on length of stay. The mechanisms of impact were categorized into those relating to patients, the technology, or the organization of health care and clinical practice.
Results: New health technologies have a variable impact on length of stay. Technologies that lead to an increase in the proportion of sicker patients or increase the average age of patients remaining in the hospital lead to an increase in individual and average length of stay. Technologies that do not affect or improve the inpatient case mix, or reduce adverse effects and complications, or speed up the diagnostic or treatment process should lead to a reduction in individual length of stay and, if applied to all patients with the condition, will reduce average length of stay.
Conclusions: The prediction framework we have developed will ensure that the characteristics of a new technology that may influence length of stay can be consistently taken into consideration by assessment agencies. It is recognized that the influence of technology on length of stay will change as a technology diffuses and that length of stay is highly sensitive to changes in admission policies and organization of care.

Keywords: Forecasting, Length of stay, Health-care technology

Inpatient hospital care is a major contributor to health-care costs, and reducing the average length of stay is considered a key goal for many health systems. Average length of hospital stay has declined in most countries, including England, since the 1940s. However, in England, average length of stay increased between 1999/2000 and 2000/2001 from a mean of 7.7 days to 8.2 days (9). In general medicine, the mean length of stay increased from 7.7 days in 1999/2000 to 7.8 days in 2000/2001, and continued to increase to 8.3 days by 2002/2003. In general surgery, average length of stay increased over the same time period from 5.5 days to 5.8 days. We were invited by the Department of Health (England) to investigate their hypothesis that the increase in average length of stay was related to the introduction of new health-care technologies.

Many factors are known to influence the length of hospital stay and include (i) characteristics of the patients such as age, sex, and comorbidities; (ii) characteristics of the health-care system such as the supply of hospital beds, staffing levels, and availability of alternative services; (iii) the organization of hospital care such as the availability of operating theaters, and the time taken for diagnostic investigations; and

Sue Simpson and Claire Packer are funded by the Department of Health and Andrew Stevens and James Raftery by the National Health Service for England.

(iv) the clinical practice style such as the surgical technique and anesthesia used (20). An Australian study found that only six factors were important: the severity of the patients' illness, the number of complications, the number of comorbidities, the efficacy of the treatment, the use of day-case surgery, and the availability of nursing homes (29). Any new technology that affects any of these factors has the potential to impact on the length of individual hospital stay and the average length of stay. Of course the relevance of the patient factors is far greater for technologies that impact on the nature of the patient group.

Early assessments of the potential impact of emerging health technologies, to identify those that may have a significant positive or negative impact on health systems, should include an estimate of the possible impact on length of hospital stay. However, prediction is not a precise process, and there are known difficulties in predicting the impact of new and changing technologies on health care (4). No predictive tools for estimating potential impact on length of stay are available, instead rough estimates are built up using experience gained from the introduction of similar technologies in the past. By using case studies identified in the literature, we developed a framework to predict the impact of new health technologies on average length of hospital stay.

METHODS

We undertook a literature search on the EMBASE, MEDLINE, Web of Science, and the Health Management Information Consortium (1) databases to identify papers that discuss the impact of new technology on length of hospital stay and reports of specific technologies impacting on length of stay. Search terms included "Length of stay," "Hospital stay," "Length of hospital stay," "Hospitalization," "Hospital stay duration," "Technology," and specific technology names as appropriate. We asked members of the International Network of Agencies for Health Technology Assessment (INAHTA) for any reports, either general or specific, on the impact of new technology on length of stay. From these searches, we identified case studies of health technologies reporting an impact on hospital stay that also proposed a mechanism of impact and categorized these mechanisms into those that operated by means of changes in the characteristics of the patients receiving the technology, those that were directly related to the new technology, and those that impacted on the organization of health care, health systems, or clinical practice. For each mechanism, we noted the direction of effect on average length of stay in our prediction framework.

RESULTS

Patient Characteristics

In general, if a new hospital-based technology expands, the indicated population to include older or sicker patients, then the average length of stay will increase (8;27). A new hospital-based technology with fewer adverse effects should reduce length of stay but may also reduce the diagnostic or treatment thresholds so that patients with characteristics that increase length of hospital stay now access treatment for a condition that was previously untreated (3;6;15). A new hospital-based technology for a group of patients who are currently only managed in the community may increase length of stay for the specific condition but may have a variable impact on average length of stay for the clinical specialty. Conversely, if the application of a hospital-based technology moves care from sicker patients to include the "less sick" by reducing diagnostic or treatment thresholds, then average length of stay may decrease, even though the number of patients receiving care may increase (12).

Technology-Related

Provided that they do not expand the client group to sicker patients, less-invasive or safer technologies, such as percutaneous transluminal coronary angioplasty (PTCA), breast-conserving surgery, and minimally invasive two-incision surgery for total hip replacement, should decrease average length of stay by reducing the recovery time in hospital or prolonged stays arising from the complications of older, more-invasive, or less-safe techniques (4;16;21). Some intensive technologies, such as coronary artery bypass grafting and chemotherapy regimens, even though potentially effective in the longer-term, can be associated with adverse effects that may increase average length of stay (2;5). If a new technology prevents a disease, reduces the recovery period, or the severity of a condition that is currently associated with an inpatient hospital stay, it may reduce the average length of stay if applied equally to the existing patient group (15). Examples include meningitis, influenza, and pneumococcal immunizations; primary and secondary prevention programs for cardiovascular disease (11); and the use of specific new technologies such as bioactive skin substitute in pediatric burns (17), new antibiotics in methicillin-resistant *Staphylococcus aureus* (28), and new inhalers for asthma (26).

Technologies may improve in-hospital survival, leading to an increase in average hospital stay (7). If a technology increases the suitability of treatment as a day case or the technology is easier or simpler to undertake than current practice, such as the use of local anesthesia in inguinal hernia repair, circumferential mucosectomy hemorroidectomy, and microwave endometrial ablation for heavy menstrual periods, this change can lead to a reduction in length of stay for a proportion of patients (18;22;24). However, the patients who are not suitable for day-case surgery will still need to be treated in the hospital and are more likely to be older and sicker. Therefore, contrary to first impressions, average length of inpatient stay for the specific condition may actually increase as the number of day cases increases.

New diagnostic tests may impact on length of stay. In one reported study, abdominal computer tomography (CT) in the evaluation of acute pancreatitis increased length of stay (10). Newer diagnostic point-of-care technology can reduce emergency department stay and reduce hospital admissions and length of stay (14;23). It is uncertain what effect this reduction may have on average length of hospital stay, but potentially, it could increase length of stay, as patients with less-severe or nonexistent disease are discharged directly from emergency departments, leaving those with more-severe disease in the hospital.

Organization of Health-Care, Clinical Practice, and Health Systems

A move from inpatient to outpatient care; provision of intermediate or home care; the development of a pharmaceutical treatment for a condition that previously required surgery, for example H_2-receptor antagonists in peptic ulcer disease; home monitoring devices; and home dialysis, if applied across all suitable candidates, could prevent or decrease individual length of stay. However, if the new practice is only applied to younger or fitter patient or patients with suitable carers at home, then the case mix of the remaining hospital-based patients will change and average length of stay may increase. If a new intervention requires new skills to be learned, then during the learning phase the average length of stay may increase before the benefits of a reduced length of stay are seen (13;19;25).

Table 1 shows our predictive framework with the estimation of the direction of impact on length of stay compared with current interventions. Overall, there are seven circumstances that may lead to an increase in average length of stay, one circumstance that leads to an initial increase in average length of stay as the technology is adopted, and one that would not affect average length of stay but may increase an individual's total lifetime bed days for a condition. There are five circumstances that may lead to a decrease in average length of stay, one depending on how the technology is implemented. There is one circumstance that would lead to a neutral effect on average length of stay with an increase in an individual's total bed days for a condition, one circumstance that would have a neutral effect on length of stay with a decrease in total bed days, and one that may lead to a decrease in length of stay according to how the technology is implemented. There are two circumstances for which there could be either an increase or a decrease in length of stay, according to how the technology is implemented and whether this implementation leads to changes in case mix.

DISCUSSION

Length of inpatient stay is rarely the primary outcome of clinical trials, particularly where it is not perceived to be an important attribute of a technology. Therefore, in many cases, information on the impact of a technology on length of stay is not available or published in the early research findings that most early warning and horizon scanning systems use. Where data on change in length of stay are available from clinical trials, it may be possible to calculate potential savings in bed days, but even in these situations, translating this calculation to all patients with any condition or presenting to the hospital for treatment will be difficult, if not impossible.

New health technologies do appear to have an impact on length of stay and average length of stay, but any effect is not consistent in direction. Technologies that lead to an increase in the proportion of sicker patients or increase the average age of patients remaining in the hospital will lead to an increase in individual and average length of stay. Technologies that either do not alter or improve the case mix, or reduce adverse effects and complications, or speed up the diagnostic or treatment process will probably lead to a reduction in individual length of stay and, if applied to all patients with the condition, should reduce average length of stay. In addition, many technologies have two or more characteristics that impact differentially in direction and magnitude on length of stay.

The prediction framework we have developed ensures that the characteristics of a new technology that may influence length of stay can be consistently taken into consideration in any forward look. This feature may help overcome some of the uncertainties involved in predicting impact. We believe that the prediction framework can be applied to technologies that are directly associated with an inpatient stay, replace a technology that is associated with an inpatient stay, or prevent or palliate a disease that is associated with an inpatient stay.

In using the framework, it should be recognized that the influence of technology on length of stay is a moving entity. As a technology diffuses, users should become more proficient in its use, adjunct therapies may be developed to increase effectiveness or reduce risks and complications, alternative technologies may enter the market, and a technology may be applied in a different clinical situation or for different clinical indications. All of these factors will influence a new technology's impact on length of stay.

Policy Implications

Using the prediction framework should enable early warning and assessment systems, such as the National Horizon Scanning Centre in England and Wales, to consistently scrutinize technology and patient-related characteristics of new technologies and identify those that have the potential to impact on individual or average length of stay. Although, average length of stay is a widely used measure, it is highly sensitive to changes in admission policies not related to technology development or implementation. In relation to the introduction of new technologies, an argument could be made that, as well as measures of length of stay, measures such as the case mix of patients receiving inpatient care should be recorded.

Table 1. Predictive Framework to Assess Potential Direction of Impact of New Technologies on Average Length of Hospital Stay

Technology-related determinant of length of stay	Technology characteristics The new technology is:	Probable effect on average length of stay
Patient characteristics		
Age/comorbidities/social circumstances	Indicated for an older age group of patients than the patients treated by current options (treatment expansion)	Increase
Severity of illness	Indicated for patients with more-severe disease than the patients treated by current options (treatment expansion)	Increase
	Indicated for patients who are less severely affected than the patients treated by current options (treatment expansion)	Decrease
No current treatment	Indicated for a patient group for whom there are no current treatments available that result in an inpatient stay	Increase
Technology characteristics		
Invasiveness and adverse effects/complications	Less invasive and/or associated with fewer side effects and complications than current treatment options	Decrease
	More invasive and/or associated with more side effects and complications than current treatment options	Increase
	More effective at decreasing the side-effects of a procedure compared to current treatment options	Decrease
Use of inpatient facilities	Requires repeat inpatient stays compared to current treatment options	Neutral but increase in lifetime bed days
	Requires extended inpatient treatment compared to current treatment options	Increase
	Eliminates the need for further inpatient treatment, inpatient treatment or prevents the disease	Neutral but decrease in total bed days
Time	Reduces intervention time compared to the current treatment option	Decreased or Neutral
	Reduces diagnostic time compared to the current diagnostic option	Decrease if the inpatient diagnostic process is shortened
	Leads to faster cure/control of disease and a shorter recovery period than the current treatment option	Decrease
Survival	Increases survival time in hospital	Increase
	Increases survival time but does not require a hospital stay or may require repeated short admissions	Decrease or neutral but increase in bed days over time
Diagnostic expansion	Increases detection and treatment rates that require inpatient services	Increase—if new patients are older; or decrease—if new patients are younger
Organization of health care, health systems, or clinical practice		
Level of service	Moves care from inpatient care to outpatient, primary care or home care, or to day-cases	Decrease—if applied to all patients; increase—if it changes case mix of patients remaining in inpatient care
	Moves care from outpatient, primary care, or no care, to in-patient care	Increase
Skill level/experience required	Involves a new technique that requires new skills or training	Increased initially

CONTACT INFORMATION

Sue Simpson, PhD, BSc(Hons) (s.l.simpson.20@bham.ac.uk), **Claire Packer**, BMBS, MFPH (c.packer@bham.ac.uk), Senior Clinical Lecturer, **Andrew Stevens**, MBBS, FFPH (a.j.stevens@bham.ac.uk), Professor, National Horizon Scanning Centre, Department of Public Health and Epidemiology, The University of Birmingham, Edgbaston, **James Raftery**, PhD, Director, Health Economics Facility, Health Services Management Centre, The University of Birmingham, Edgbaston, Birmingham B15 2TT, UK

REFERENCES

1. Health Management Information Consortium database. Available at: www.hsmc.bham.ac.uk/library/. Accessed December 24, 2004.
2. Aranki SF, Shaw DP, Adams DH, et al. Predictors of atrial fibrillation after coronary artery surgery. Current trends and impact on hospital resources. *Circulation*. 1996;94:390-397.

3. Bates DW, Spell N, Cullen DJ, et al. The costs of adverse drug events in hospitalized patients. *JAMA.* 1997;277:307-311.
4. Bloom BS, de Pouvourville N, Libert S, Fendrick AM. Surgeon predictions on growth of minimal invasive therapy: The difficulty of estimating technologic diffusion. *Health Policy.* 2000;54:201-207.
5. Chrischilles E, Delgado DJ, Stolshek BS, et al. Impact of age and colony-stimulating factor use on hospital length of stay for febrile neutropenia in CHOP-treated non-Hodgkin's lymphoma. *Cancer Control.* 2002;9:203-211.
6. Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients. Excess length of stay, extra costs, and attributable mortality. *JAMA.* 1997;277:301-306.
7. Combier E, Levacher S, Letoumelin P, et al. Cost-effectiveness analysis of the terlipressin-glycerin trinitrate combination in the pre-hospital management of acute gastro-intestinal haemorrhage in cirrhotic patients. *Intensive Care Med.* 1999;25:364-370.
8. Creed F, Tomenson P, Anthony P, Tramner M. Predicting length of stay in psychiatry. *Psychol Med.* 1997;27:961-966.
9. Department of Health. *Hospital episode statistics*. Available at: www.dh.gov.uk/publicationsandstatistics/statistics/hospitalepisodestatistics/fs/en. Accessed December 24, 2004.
10. Fleszler F, Friedenberg F, Krevsky B, Friedel D, Braitman LE. Abdominal computed tomography prolongs length of stay and is frequently unnecessary in the evaluation of acute pancreatitis. *Am J Med Sci.* 2003;325:251-255.
11. Foster C, Murphy M, Nicholas JJ, Pignone M, Bazian Ltd. Cardiovascular disorders: Primary prevention. In: *Clinical evidence,* vol 11. London: BMJ Publishing Group; 2004:163-196.
12. Gelijns A, Rosenberg N. The dynamics of technological change in medicine. *Health Aff.* 1994;13:28.
13. Grady KL, Haller KB, Grusk BB, Corliss JW. Predictors of hospital length of stay after heart transplantation. *J Heart Transplant.* 1990;9:92-96.
14. Lee-Lewandrowski E, Corboy D, Lewandrowski K, et al. Implementation of a point-of-care satellite laboratory in the emergency department of an academic medical center: Impact on test turnaround time and patient emergency department length of stay. *Arch Pathol Lab Med.* 2003;127:456-460.
15. Lichtenberg FR. Do (more and better) drugs keep people out of hospitals? *Health Econ.* 1996;86:384-388.
16. Lindqvist R, Moller TR, Stenbeck M, Diderichsen F. Do changes in surgical procedures for breast cancer have consequences for hospital mean length of stay? A study of women operated on for breast cancer in Sweden, 1980–95. *Int J Technol Assess Health Care.* 2002;18:566-575.
17. Lukish JR, Eichelberger MR, Newman KD, et al. The use of a bioactive skin substitute decreases length of stay for pediatric burn patients. *J Pediatr Surg.* 2001;36:1118-1121.
18. Milligan M. Curtain down on period drama. *Health Serv J.* 2003;113:27.
19. Mohr P, Mueller C, Neumann P, et al. *The impact of medical technology on future health care costs*. Maryland: Project Hope Center for Health Affairs; 2001.
20. Morgan M, Beech R. Variations in length of stay and rates of day case surgery: Implications for the efficiency of surgical management. *J Epidemiol Community Health.* 1990;44:90-105.
21. National Institute for Clinical Excellence. *Interventional procedure overview—minimally invasive two-incision surgery for total hip replacement.* Available at: www.nice.org.uk/pdf/ip/240overview.pdf. Accessed September 20, 2004.
22. O'Connor H, Broadbent JAM, Magos AL, McPherson K. Medical Research Council randomised trial of endometrial resection versus hysterectomy in management of menorrhagia. *Lancet.* 1997;349:897-901.
23. Roberts R, Zalenski RJ, Mensah EK, Rydman RJ. Costs of an emergency department-based accelerated diagnostic protocol vs hospitalization in patients with chest pain: A randomized controlled trial. *JAMA.* 1997;278:1670-1676.
24. Rowsell M, Bello M, Hemingway DM. Circumferential mucosectomy (stapled haemorrhoidectomy) versus conventional haemorrhoidectomy: Randomised controlled trial. *Lancet.* 2000;355:779-781.
25. Sloan FA, Valvona J. Why has hospital length of stay declined? An evaluation of alternative theories. *Soc Sci Med.* 1986;22:63-73.
26. Stempel DA, Yancey SW. Addition of salmeterol decreases hospitalization, length of stay and does not add to direct costs of asthma care. *J Allergy Clin Immunol.* 1999;103:S60.
27. Stoskopf C, Horn SD. Predicting length of stay for patients with psychosis. *Health Serv Res.* 1992;26:743-766.
28. Willke RJ, Glick HA, Li JZ, Rittenhouse BE. Effects of linezolid on hospital length of stay compared with vancomycin in treatment of methicillin-resistant *Staphylococcus* infections. An application of multivariate survival analysis. *Int J Technol Assess Health Care.* 2002;18:540-554.
29. Xiao J, Douglas D, Lee AH, Vemuri SR. A Delphi evaluation of the factors influencing length of stay in Australian hospitals. *Int J Health Plann Manage.* 1997;12:207-218.