

# Improving Medication Safety: Bedside verification

## Cost Utility Analysis



\* **This is an example of a data matrix**, two-dimensional barcode. The information to be encoded can be text or raw data. Data matrix symbol can store up to 2,335 alphanumeric characters.

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This analysis is based on the best information available at the time the report was prepared. All care has been taken but many factors cannot be accurately determined and a lot of this information will depend on detailed planning and tender processes. In developing this analysis the author has attempted where possible to take a conservative approach.

This paper was prepared by Dr Bruce Anderson PhD. Any errors of fact or interpretation are the responsibility of the author. James Harris of LECG, Elizabeth Plant, Chief Pharmacist at Taranaki DHB and Win Bennett General Manager Funding and Planning at Hawkes Bay DHB are thanked for reviewing earlier drafts. Also thanked for their input are Pharmac, Quality Improvement Committee, Safety and Quality Use of Medicines Committee, the Health Information Strategy Action Committee, and the Accident Compensation

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## EXECUTIVE SUMMARY

This cost utility analysis provides further detail to the consultation document *Improving Medication Safety: Bedside verification*. It is recommended that the consultation document is read first.

It is estimated that the gross cost over twelve years of a proposal to introducing and then operating bedside verification of medication in DHB hospitals would be in the order of \$101M<sup>1</sup>. This consists of capital expenditure of about \$44 million; implementation costs of about \$10M; and ongoing annual operating costs of between \$3.5M to \$5M.

The gross cost of the project will be offset firstly by a potential saving over the first twelve years of about 1,050 lives; preventing about 2,800 people being subject to permanent disabilities; and about 29,000 shorter term disabilities. Secondly, in financial terms reducing the incidence of medication error will reduce the need for those subject to the adverse medication events needing to spend extra time in hospital. On average, those subject to a medication error need to spend an additional 7.5 days in hospital on top of the days required for the original health problem. Preventing this unnecessary time in hospital could eventually free up about \$26M of resources each year for other priorities. The total net discounted saving over twelve years would be in the order of \$115M. A sensitivity analysis of the major assumptions suggests that the analysis is robust notwithstanding the uncertainties that will be determined by once consultation has been completed and project details further developed.

## INTRODUCTION

This cost utility analysis supports a consultation document on the introduction of bedside verification of drugs using barcode point of care and associated systems. A cost-utility analysis examines outcomes that are weighted in a common currency, usually quality-adjusted life years (QALYs). QALYs combine changes in the quantity and quality of life (mortality and morbidity) into one composite measure. A cost-utility analysis enables comparison between the cost-effectiveness of interventions treating different conditions, and also takes into account benefits resulting from both decreases in mortality and decreased morbidity<sup>2</sup>.

Due to the nature of this proposal, the following cost utility analysis only provides an indication of the potential costs and benefits. Estimates in many areas are best estimates and further project development and consultation will allow costs and benefits to be better determined. Estimated impacts of implementing barcode standards in New Zealand are made on a national basis; costs and benefits are however likely to vary from region to region.

<sup>1</sup> Costs and benefits have been discounted at 3.5 percent unless stated otherwise.

<sup>2</sup> *Prescription for Pharmacoeconomic Analysis: Methods for cost utility analysis*, Pharmac, version 2, July 2006.

While the costs of requiring barcode use and having them printed on packaging are minimal, so would be the benefits achieved from that option alone. The maximum gain would come from introducing point-of-care systems into DHB hospitals and linking those systems to DHB patient management and other systems.

This analysis is premised on barcode systems at unit dose level but in the short to medium term, unit dose repackaging of medication is undertaken. To ensure standardised implementation, Government would financially support the implementation of point-of-care and associated systems in DHBs. Private health care organisations would make their own business decisions as to implementing point-of-care systems, but could be provided an opportunity to piggy-back on DHB implementation at their own cost.

### **COSTS AND COST OFFSETS**

This analysis considers the following areas,

- project, regulatory and business compliance costs . includes project development and system implementation, modifications to the pharmaceutical database, and developing the necessary regulation and for industry to implement those regulations.
- proposal costs . capital costs to purchase barcode scanners, unit dose repackaging machines, information technology costs associated with hospital pharmacy upgrades, bedside verification systems (BPOC) and developing the links between these systems and the patient management system.
- cost offsets . patient lives saved or a reduction of other adverse events through a reduction in medication errors; reduction in average length of stay due to adverse drug events, savings through pharmaceutical supply chain efficiency gains, and reduction in ACC medical misadventure claims.
- cost utility analysis - comparison between the cost-effectiveness of intervention
- a sensitivity analysis to assess the robustness of certain assumptions

Table 1 presents an estimate of the costs and benefits associated with requiring barcode use and the implementation of point-of-care systems in DHB hospitals. Costs have been split in a two year implementation period and the first 10 years of use. By the end of Implementation Year 1, 25 percent of DHBs will have implemented the system and by the end of Year 2, full nationwide implementation will have occurred. Although benefits start accruing from the moment the system is implement (when the first warning is provided to a nurse attempting to administering a medication), for planning a lag has been assumed. The assumption is that 13 percent of benefits would be realised in the end of the first year, 63 percent in the second and the full benefit by the end of the third.

**Table 1: Summary of costs and cost offset for the implementation of bedside verification using barcode at point of care and associated systems**

All figures in NZ\$ millions	Implementation						Outyears					
	Project Years		1	2	3	4	5	6	7	8	9	10
	% implemented	% of benefits realised	25%	75%	100%	100%	100%	100%	100%	100%	100%	100%
<b>Regulation</b>												
Policy and project			2.50	2.50	1.00							
Pharmaceutical database changes			0.50	0.50								
Medsafe regulation development				0.10	0.10							
Compliance costs assoc. with label changes					0.20	0.80	0.80	0.20				
<b>Subtotal regulation</b>			<b>3.00</b>	<b>3.10</b>	<b>1.30</b>	<b>0.80</b>	<b>0.80</b>	<b>0.20</b>				
<b>Hospital Costs</b>												
Upgrade DHB Rx Supply Chain systems			0.50	0.50								
Hospital pharmacy upgrades			5.00	5.00								
Unit dose repackaging machines			2.25	0.75								
Maintenance			0.23	0.30	0.30	0.30	0.30	0.30				
Unit dose repackaging (50 million doses)			0.17	0.84	1.35	1.35	1.35	1.00				
Barcode POS systems			5.25	15.75								
Ongoing costs @10% of initial capital			0.53	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
PMS connections			0.50	0.50								
E-prescribing/e-medicine record/CPOE			0.25	0.75	3.50	10.50						
E-prescribing etc maint/lease					0.35	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Contingency 10%			1.47	2.65	0.76	1.57	0.52	0.52	0.52	0.35	0.35	0.35
<b>Subtotal Hospital Costs</b>			<b>16.15</b>	<b>29.14</b>	<b>8.36</b>	<b>17.22</b>	<b>5.67</b>	<b>5.67</b>	<b>5.67</b>	<b>3.85</b>	<b>3.85</b>	<b>3.85</b>
<b>Cost offsets</b>												
Reduction in LOS: Deaths			-0.09	-0.47	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76
Permanent Disability			-0.25	-1.27	-2.03	-2.03	-2.03	-2.03	-2.03	-2.03	-2.03	-2.03
Disability 1 - 12 months			-0.38	-1.91	-3.06	-3.06	-3.06	-3.06	-3.06	-3.06	-3.06	-3.06
Disability < 1 month			-2.20	-11.00	-17.60	-17.60	-17.60	-17.60	-17.60	-17.60	-17.60	-17.60
Impact undefined records			-0.13	-0.64	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03
Rx supply chain efficiency gains			-0.21	-1.06	-1.70	-1.70	-1.70	-1.70	-1.70	-1.70	-1.70	-1.70
ACC med misadventure claims reduction												
<b>Subtotal cost offsets</b>			<b>-3.27</b>	<b>-16.37</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>	<b>-26.18</b>
Gross costs			19.14	32.24	9.66	18.02	6.47	5.87	5.67	3.85	3.85	3.85
Offsets			-3.27	-16.37	-26.18	-26.18	-26.18	-26.18	-26.18	-26.18	-26.18	-26.18
<b>Net costs (saving if negative)</b>			<b>15.86</b>	<b>15.88</b>	<b>-16.52</b>	<b>-8.17</b>	<b>-19.72</b>	<b>-20.32</b>	<b>-20.90</b>	<b>-22.33</b>	<b>-22.33</b>	<b>-22.33</b>

## **Regulatory and business compliance costs**

### *Policy and project*

While the scope and nature of the proposal are currently under consultation preliminary views on how a project like this could operate have been broadly considered. It is envisaged that this project would be centrally facilitated with key clinical staff (nursing, medical and pharmacist) drawn from DHBs. The individuals would have, or develop, experience of the different bedside verification and associated systems available, their availability, functionality and their implementation characteristics. These individuals would form the group that would act initially as the ~~on~~ the ground+implementers and would train the trainers for the initial DHB pilot.

Each components of the overall project would be lead by an individual with specialist knowledge in a particular area. For example, the upgrade of DHB pharmacy systems would be led by a DHB pharmacist and there would be an expectation that this person would work with other DHB pharmacists to develop the business requirements, scope system specification, review options and following lead the tender process. Other components such as the unit dose repackaging and the bedside verification system would be similarly managed. Project managers and other non-clinical support would be commissioned as needed for each of the project components.

### *Database changes*

Each pharmaceutical item needs to have a standardised, globally unique identifier that is international recognised. New Zealand currently has an identifier which is proprietary and locally derived - Pharmacode. The Pharmacy Guild manages the allocation of Pharmacode numbers and administers a database of those numbers. Pharmacode numbers are not globally unique and as such are not used by Australia or any other country. In addition, using two unique identifiers can cause problems because of the need to map one number to the other and the additional costs to maintain two systems. Finally, within the data structure of the Pharmacode there is not the ability to carry additional information such as batch and expiry. Notwithstanding the need to move to a globally standardised pharmaceutical identifier, it is believed that the Pharmacy Guild provides an important service managing the database and at this it is not envisage that this would change.

As a unique identifier the Food and Drug Administration of the United States of America requires medication to use a National Drug Catalogue (NDC) number. Internationally most other jurisdictions use a Global Trade Identification Number (GTIN) which is a standard of the international standards organisation . GS1. A GTIN currently has global acceptance, has wide penetration in other industry sectors and has a well developed infrastructure to manage the issuing and monitoring of standards and numbers. It is proposed that a single standard of barcodes be used in New Zealand and the GTIN is the primary unique identifier for all pharmaceuticals.

The original development of the database was funded by Pharmac. Pharmac officials assert that it would cost an estimated \$2M to migrate from the Pharmacode to a GTIN based numerology or some other unique identifier for the medication (although the original database cost considerably less to develop). This cost would be offset against having New Zealand's barcode data structure the same as other purchasers, and therefore pharmaceutical manufacturers not having to produce uneconomic, small single product runs specifically for New Zealand. This also suggests the need for a consistent labelling regime across Australia and New Zealand.

### *Development of Regulations for unit dose packaging*

In order to conform to Medsafe regulations, pharmaceutical manufacturers are currently required to label drugs destined for the New Zealand market with well defined packaging information (ie, registration number, application information, etc). Moving towards a regime of standardised barcoding would provide the opportunity for New Zealand to benefit from economies of scale, through harmonised trans-Tasman packaging costs.

Costs in this area would be incurred in a later phase and would relate to Medsafe (or ANZTPA) developing labelling standards, consulting on those standards and subsequently issuing regulation of packaging standards. As described above this process may take some time and as a consequence unit dose repackaging would be undertaken. Alternatively, it could be argued that the addition of a barcode is a small change to packaging that could be readily accommodated.

### *Cost to manufacturers of changing packaging*

In changing a label, manufacturers have defined processes they are required to follow. In general, the costs relate to the number of stock items labels to be modified, artwork development, printing system modifications, possible inventory loss due to obsolete packaging, and any changes to packaging dimensions to accommodate additional information. Costs associate with changing labels can be minimal if the changes can be accommodated within existing production and packaging systems. Should the change require larger packet or blister packs then there may be a requirement for manufacturers to retool. It is likely that a change of this magnitude will be expensive for manufacturers and those costs would be passed on to pharmaceutical purchasers.

The GS1 New Zealand audit identified that 46 percent of items destined to be used in local hospital and community pharmacy channels were packaged with machine readable barcodes at ~~retail~~package level<sup>3</sup>.

A phased introduction would allow manufacturers to update packaging as stocks need replacing. Package redesign is likely to incur a one-off cost per package type.

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<sup>3</sup> As distinct from logistics units such as pallets and cartons etc

The type of barcode format is likely to impact on the implementation costs. If two dimensional barcodes are used the impact on packaging lines is likely to be considerably less as these barcodes will be able to be placed readily on existing packages. This is because small barcodes can be placed on existing packages without the need for manufactures to invest in new machinery to accommodate larger packages.

Pharmac currently make considerable savings for New Zealand by purchasing pharmaceutical in bulk lots. Moving to a mandate of individually packaged items will shift the cost of packaging to the manufacturer and they are likely to pass that cost to Pharmac and DHBs. This cost has not been quantified at this time. However, whatever the cost, if New Zealand packaging was consistent with larger markets that were also using pharmaceutical in the unit of dose could lessen the impact of any cost increase.

### **System implementation costs**

Decisions on fund mechanisms for the bedside verification project have yet to be made. The main costs in implementing bedside verification using a barcoding system are likely to be related to the one-off purchase of capital equipment (specifically barcode scanners and machines to repackage bulk quantities of pharmaceuticals into unit doses). Costs associated with the standardisation and interconnectivity of pharmacy IT systems and the linking of that system to the patient management system and BPOC will also be a factor. Other costs will include the time lost by staff as they are involved in the implementation and trained on the systems. Recurring costs would also arise, associated with the maintenance and upkeep of software and scanner systems.

#### *Standardise pharmacy information and dispensing systems*

As described in earlier sections, the introduction of a BPOC system will require it to be linked to the pharmacy information system. If the current pharmacy systems were used the wide range of systems would mean that multiple links between the pharmacy system and the BPOC system would need to be developed. This would create an unacceptable risk. A more cost effective and efficient approach is to standardise the pharmacy system across DHBs.

An estimate of upgrading to, for example, the Ascribe Pharmacy System would be about \$400,000 for a 250 bed hospital system and \$450,000 for a 1000 bed hospital system. On this basis the cost to standardise would be in the order of one-off cost \$10M. An annual maintenance/support fee of \$80,000 per system would also be payable. This annual costs would be paid by DHBs as part of their normal business operating costs. As the majority of DHBs currently use one of the two most popular pharmacy systems the costs are likely to be less than \$10M as not all DHBs would need to change.

*Unit dose repackaging*

Depending on any final barcode regulations, either manufacturers would be required to package at unit dose level or, alternatively, DHBs (or some other contracted organisation) would need to repackage pharmaceuticals into unit doses. Clearly, if the rule requires manufacturers to supply pharmaceuticals barcoded at unit dose level then there would be no need to purchase unit dose repackaging machines. The cost to manufacturers of providing pharmaceuticals in unit doses are discussed above in the Regulatory and business compliance costs section.

In the short-term, the purchase of repackaging machines means that individually wrapped medications labelled with barcodes will speed to implementation of the project. This could be achieved by, for example, six machines located in each of Dunedin, Christchurch, Wellington, Palmerston North, Hamilton, and Auckland. Alternatively, a stand-alone organisation could repackage to unit dose level for all of New Zealand. An estimate provided for a 500 canister oral dose repackager is NZ\$450,000. A \$50,000 installation fee and an annual maintenance and support fee of \$50,000 would also be payable<sup>4 5</sup>. A one-off capital cost of approximately NZ\$2.25M in the first year and the balance of \$0.75M in the second would be required.

Current estimates on the cost of repackaging pharmaceuticals to unit dose are in the region of \$0.027 per dose. No data exists on the amount of individual doses dispensed in New Zealand. Taranaki DHB currently uses Pyxis cabinets which are able to run reports on the amount of drugs dispensed from them. Therefore an order of magnitude estimate can be extrapolated from the volumes dispensed from Taranaki to the all New Zealand DHB hospitals. Taranaki DHB dispenses about 625,000 doses each year. Hospital pharmaceutical expenditure by Taranaki DHB is about two percent of total New Zealand-wide DHB pharmaceuticals expenditure. On this basis a rough estimate is 30 million doses are issued each year in DHB hospitals. To account for unforeseen inaccuracies and growth in usage this estimate is raised to 50 million doses. At \$0.027<sup>6</sup> per dose the annual cost of repackaging DHB pharmaceuticals could be around \$1.35M per annum.

Without the introduction of regulation in subsequent years the repackaging machines would need to be replaced due to technological advancement and normal wear and tear. The life expectancy of these machines is likely to be in the order of 5-10 years (dependant on model and use). This cost utility analysis assumes a five year replacement cycle and that by the end of the first cycle that regulation would have been developed and phased in, therefore there be no need to replace the repackagers as pharmaceuticals would be packaged by the manufacturer or supplier.

<sup>4</sup> Estimate provided by Cardinal Healthcare Ltd.

<sup>5</sup> Consistent with estimate provided by Ron Schneider (Consultant Pharmacist), Veterans Administration Hospital, Washington, USA . machines cost about US\$180,000 to US\$300,000 per unit with many suppliers.

<sup>6</sup> **Cost of packaging per unit -----**

### *Patient Point of Care Systems*

The cost of a patient point of care system (BPOC) system will depend on

- type, scope and extent of system chosen and add-ons provided
- decisions on New Zealand building its own system or purchasing an already developed system
- linking of the BPOC to other components such as the patient management and pharmacy systems
- competition through international tendering
- possible support provided by preferred provider

Other organisations have faced similar considerations when faced with decisions about the implementation of bedside verification using BPOC systems.

- The United States Food and Drug Administration (FDA) considered the cost of implementing point-of-care barcoding systems in hospitals. The FDA<sup>7</sup> determined the average initial cost to a typical hospital (of 170 beds) for the installation of scanners, readers, software, initial training and so on, as US\$448,000 and in another example<sup>8</sup> of an average 191 bed hospital; one-off costs of US\$369,000 and annual costs of US\$103,000 (equivalent to about NZ\$554,000-\$672,000 per hospital and annual costs of NZ\$155,000).
- A recent installation of a barcode point-of-care system across a nine facility group in the United States cost US\$3.1M<sup>9</sup> (equivalent to about NZ\$4.7M or NZ\$520,000 per hospital).
- Healthcare of America (HCA) recently completed an installation of BPOC, electronic medication record and local pharmaceutical repackaging across its 182 hospital chain at a cost of about US\$30M<sup>10</sup> (equivalent to about NZ\$45M or \$NZ236,000 per hospital).
- The Bridge Medical Group is a provider of BPOC and associated systems and have published that to implement their system in a 300 bed hospital with 15,000 admissions each year would cost US\$0.70-US\$1.5M and with annual costs of about \$0.15M<sup>11</sup> (equivalent to about NZ\$1,05M-2.25M and \$NZ225,000 per annum).

<sup>7</sup> Eastern Research Group, 2002; Impact of Proposed Barcode Regulation for Drug and Biologic Products, FDA Task Order 21 Contract No 223-98-8002

<sup>8</sup> Tucker, S.A., 2003, Analysis of the Impact of the Food and Drug Administration's Proposed Barcode Label Requirements for Human Drug Products and Blood. Proceedings of the Barcode Medication Administration Conference,

<sup>9</sup> Walton GS, Hix, K. 2003. Medication Administration: Five rights and many wrongs. *Proceedings of Health Information Management System Society Annual Conference.*

<sup>10</sup> Pers comm. Dr Jane Englebright Director Quality and Safety HealthCare of America

<sup>11</sup> May, E.L., *Healthcare Executive* Sept/Oct 2003

In the cases cited above there is a mix of capital and operational expenditure. The best comparison for New Zealand is the implementation of BPOC and electronic medication record by HealthCare of America. HCA is a leading health care services company in the United States with annual revenue of about \$24.5B. As at the end of 2005, they operated 182 hospitals and 94 freestanding surgery centers. Annually, HCA hospitals receive about 1.65M inpatient admissions. Hospitals are organised into regional groups controlled by local boards. The company has grown through mergers with other hospital providers and as a result, prior to implementation of BPOC, there were a wide range of pharmacy, patient management and IT infrastructure systems needing to be standardised. It would appear from discussions with HCA implementation leaders that the drivers for introduction of bedside verification, the considerations on types of system and the challenges are (or are likely to be) similar to New Zealand and therefore, HCA a good indicator for possible costs.

An estimate of the average capital cost to implement BPOC for New Zealand could be on average NZ\$1.0M for each DHB. Other costs are separately identified, for example project costs, e-prescribing (or e-medicine chart), and inter-connectivity of systems. Savings are likely to be able to be achieved through the bulk purchasing of capital equipment and software, and the central provision of implementation services. It is reiterated that these are estimated costs and the actual cost would be determined dependant on the system chosen, the types of infrastructure used and competition through international tender processes.

A phased implementation would occur with selected hospitals or DHBs implementing the system in a coordinated sequence. This would allow capital outlay to be spread. On the basis of a two year phase-in, total costs across all DHBs would be in the order of \$21.8M with perhaps 25 percent expenditure in the first year (\$5.3M in the first year and \$15.8M in the second year.

#### *Electronic prescribing or electronic medication chart*

A clinician assesses a patient and decides on an appropriate course of treatment. This information is then often handwritten in the patient's medical notes. The information in those records can be illegible or transcribed into the electronic patient management or the pharmacy system incorrectly, or the course of treatment may not be the best option for the patient. Of critical importance is that there is a standardised source of prescribing information available for the pharmacy and patient point of care system to check against.

Current options are electronic medicine chart, electronic prescribing or full clinician point of entry (CPOE). All systems have in common that clinicians enter prescribing data directly into the patient's record. Some systems also allow for direct access to the latest diagnostic test results and provide decision support information (best course of treatment, interactions etc.).

Of the three options full CPOE is the most costly, takes longer to introduce and is not as easy to implement as the others or bedside verification<sup>12 13</sup>. The costs associated with developing and maintaining the decision support components can also be expensive. An estimate provided suggests costs in the order of \$500,000 for an organisation of the size of Auckland DHB and about \$250,000 for smaller DHBs. The total for this component may be in the order of \$14M. However, to a large extent this depends on the scope and nature of the system chosen.

The development and maintenance of any system chosen should be undertaken by a single provider for all DHBs. This would ensure consistency across New Zealand and reduction of ongoing costs. Annual maintenance and licensing costs could be ten percent of the capital cost and this would result in ongoing costs of about \$1.4M per annum.

### *Medication administration record systems*

A natural consequence of any BPOC system will be that medication records will become electronic. There will need to be consensus on what information should be contained on the medication record. To achieve this consensus clinical staff will lead the development of the information requirements and layout of the record. As a consequence a separate cost has been attributed to this component to account for the development of a standardised electronic medication record.

## **COST OFFSETS**

Clearly one of the major benefits to society is improved patient safety outcomes, and fewer deaths and injuries related to misadministration of drugs. A reduction in the length of stay for those who have suffered medical misadventure or mishaps would also follow. While these benefits are difficult to quantify in financial terms<sup>14</sup>, patients and their families affected by adverse events would likely agree that the benefits are immeasurable.

As described earlier, studies of the impact of implementing point-of-care barcode systems have shown a reduction in adverse drug events of between 65-86 percent<sup>15,16,17</sup>. In New Zealand, this could mean that bedside verification of medication administration using barcode systems could result in a reduction of 3,200 to 4,200 preventable adverse drug events each year. While the severity of any event will vary from no reaction to death, bedside verification using a point-of-care barcode systems could prevent 3608 to 430 deaths or permanent disabilities each year. In-patient volumes increase each year and as a result so to does the potential number

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<sup>12</sup> Neuenschwander, M., and Wisz, M, 2006; *To the Bedside 2: An Expanded Review of Barcode Point of Care Solutions*. The Neuenschwander Company

<sup>13</sup> Kinninger, T., and Kelly, J., 2003: *Prioritizing Capital Allocations: How healthcare leaders can evaluate information technology using evidence-based information*. Bridge Medical

<sup>14</sup> Davis, et al (2001).

<sup>15</sup> Malcom, et al (2000).

<sup>16</sup> Pukett (1995).

<sup>17</sup> Johnson, et al (2002).

of lives impacted without introducing some form of medication safety process or system.

### Reduction in bed days

Reducing the number of adverse drug events would reduce the need for patients to have extra time in hospital to recover from complications created by the ADE. Savings in this area alone would be substantial. In the NZHQS report<sup>18</sup> it is identified that each adverse drug event results in a mean of 7.5 additional days of hospital stay per ADE.

Multiplying the extra bed days by the number of adverse drug events prevented from implementing point-of-care barcoding systems (65 percent of the 4,781 ADEs) gives a saving of around 23,700 hospital days per annum. While the average contracted (DRG) price for is about \$2,647<sup>19</sup> per day, a better measure is gross average cost per patient per day (calculated from Ministry data), which provides a price of \$1,031 per day. This gives a saving of about \$24.5 M per annum by reducing patients having to spend additional time in hospitals. Using the average DRG price suggests a saving in the order of \$63M. However, as the extra days of hospital care are likely to relate to a broad range of additional procedures as well as recuperation time it is felt that the more conservative price per day of \$1,031 reflects the costs to the health sector.

**Table 2: Summary of bed days saved by reducing the number adverse drug events each year and the saving associate with that reduction**

ADEs prevented each year resulting in	ADEs prevented each year by BPOC (65%)	Average bed days averted	Days averted each year	Cost of day	Average cost per ADE averted	Cost averted each year
<b>Deaths prevented</b>	98	7.5	736	\$1,031	\$7,732.5	\$759,015
<b>Permanent disability prevented</b>	263	7.5	1,971	\$1,031	\$7,732.5	\$2,032,199
<b>Disability lasting between 1-12 months prevented</b>	396	7.5	2,969	\$1,031	\$7,732.5	\$3,060,541
<b>Disability lasting less than 1 month prevented</b>	2,277	7.5	17,075	\$1,031	\$7,732.5	\$17,604,230
<b>Undefined impact</b>	133	7.5	997	\$1,031	\$7,732.5	\$1,028,340
<b>TOTALS</b>	<b>3,166</b>		<b>23,748</b>			<b>\$24,484,325</b>

In general, the savings from the reduction in bed days will free up resource rather than provide a dollar return, as any spare capacity will be filled with other patients.

<sup>18</sup> Ibid Davis et al 2000

<sup>19</sup> Price is based on the Victorian cost weights (Wies8) modified by the Ministry of Health for derived 2004/05 contracted prices with DHBs. Price excludes the cost of adjusters paid to DHBs for complexity (tertiary), diseconomies of scale, M ori health, capital adjustment, acute demand and blood.

However, the freeing of resource has the potential to create additional capacity of other initiatives such as elective surgery.

**Efficiencies in DHB Provider Arm pharmaceutical supply chain**

DHBs currently spend about \$170M on pharmaceuticals for use in DHB hospitals. Barcoding of pharmaceuticals will improve inventory control and stock management, reduce wastage and provide data on usage patterns. Saving of one percent could yield a potential saving of about \$1.7M. This component should be undertaken in conjunction with PHARMAC.

**Reduction in treatment injury claims and costs to ACC**

The Injury, Prevention, Rehabilitation and Compensation (IPRC) Act 2001 covers ACC’s responsibilities in the treatment of injury and patient safety. The IPRC defines Treatment Injury as an injury caused by seeking or receiving treatment from a registered health professional. If a claim to ACC is accepted then the compensation is tailored to each particular claimants needs based on various factors including the degree of injury and the rehabilitation required.

ACC report that the 2005/06 expenditure on adverse medication events was appropriately \$816,000. This amount covers both claims from previous years that require ongoing treatment and new claims occurring within the financial year.

A reduction in medication errors would create unqualified savings to ACC and have the potential benefit of ACC being able to reduce levy charges.

**Summary of discounted costs and offsets**

Table 1 shows the breakdown of costs and offsets. This cost utility analyses discounts costs and benefits at 3.5 percent and shows results for zero, five and ten percent. Table 3 below summarises the gross costs and offsets at the varying discount rates over the first twelve years of the initiative. Over that time it will have cost DHBs about \$101M to purchase, implement and operate bedside verification of barcoded drugs at point of patient care (and associated systems). These costs would be offset mainly by approximately \$222M from reducing the number of patients affected by adverse drug events and therefore not needing additional time in hospital to recover. Over the twelve years considered in this analysis, it is forecast that net savings in the order of \$121M could be achievable.

**Table 3: Gross cost and offset over the twelve years considered in this analysis discounted at various rates**

<b>Present value (\$M)</b>					
Discount rate	3.5%		0.0%	5.0%	10.0%
Gross	\$101.33		\$115.91	\$95.68	\$81.13
Offsets	-\$221.73		-\$281.48	-\$201.35	-\$149.47
<b>Net</b>	<b>-\$120.70</b>		<b>-\$165.57</b>	<b>-\$105.68</b>	<b>-\$68.34</b>

In the next section the costs and offsets are compared against the societal benefits for the project. This approach allows bedside verification using BPOC to be compared against other initiatives.

**COST UTILITY ANALYSIS**

This section considers the costs and offsets against the societal benefits of the intervention. Societal benefits are the deaths, permanent disabilities and temporary disabilities prevented from implementing bedside verification of medication.

**Number of adverse drug events**

Below is a copy of the table provided in Appendix A that outlines the potential impact of adverse drug events. This table is an extrapolation of results obtained from the New Zealand Quality of Healthcare Study lead by Prof Peter Davis. The number of adverse drug events is calculated by multiplying the percentage of in-patient adverse events that occurred inside public hospitals by the percentage all adverse events which are preventable, drug related, and occurred inside public hospitals. This suggests that adverse drug events occur in 0.78% of admissions.

**Table 4: Adverse drug events per annum by severity of impact and possible reduction following the introduction of measures proposed in this document**

Type of Adverse Drug Event (ADE)	Percent ADE by Type (%)	Number of Patients impacted	Reduction due to BPOC (65%)	Reduction due to BPOC (78%)	Reduction with BPOC (86%)
ADEs each year resulting in <b>death</b>	3.1%	151	98	118	130
ADEs each year resulting in <b>permanent disability</b>	8.3%	404	263	315	348
ADEs each year resulting in <b>disability lasting between 1-12 months</b>	12.5%	609	396	475	524
ADEs each year resulting in <b>disability lasting less than 1 month</b>	71.9%	3,503	2,277	2,732	3,012
ADEs each year with <b>undefined impact</b>	4.2%	205	133	160	176
<b>TOTALS</b>		4,871	3,166	3,800	4,189

Briant et al (2004)<sup>20</sup> separated permanent disability from death for adverse drug events for the NZQHS case series. Permanent disability greater than 50 percent and death attributed to adverse drug events were defined as 8.3 and 3.1 percent respectively. The majority of ADEs have less sever impacts with 12.5 percent resulting in a disability lasting for between one and 12 months and 71.9 percent lasting less than one month. In the NZQHS analysis a group (4.2 percent) of patient

<sup>20</sup> Briant, R., Wasan, A., Lay-Yee, R., and Davis, P., 2004: Representative case series from public hospital admissions 1998: drug and related therapeutic adverse events. *New Zealand Medical Journal*, v 117, 1188 p8.

records did not contain sufficient information on the impact of an ADE and therefore were recorded as undefined impact.

Following implementation of bedside verification of medication using barcodes at hospitals in other jurisdictions, reported reductions of between 65-86 percent (average 78.2 percent) have been achieved. In the following analysis a 65 percent reduction in the incidence of adverse drug events attributable to bedside verification is used.

**Life years saved**

The average age of patients identified in the NZQHS review as having been subject to medication error is 58.6 years. Applying New Zealand mortality and life table data<sup>21</sup> gives a weighted average life expectancy for the NZHQS participants of 23.5 years, that is, the average number of years of life remaining for someone around 58 years old. Life expectancy represents the average longevity of the whole population and does not necessarily reflect the longevity of an individual. In this study the average life expectancy has been used rather than calculating one using age brackets, gender and ethnicity. As with other measures, life expectancy is presented discounted at 3.5 percent and with results for zero, five and ten percent (Table 5).

**Table 5: Discounted life expectancy**

<b>Present value (life years)</b>					
Discount rate	3.5%		0.0%	5.0%	10.0%
Discounted Life expectancy	15.8		23.5	13.6	8.9

A 3.5 percent discount rate reduces the duration of the benefits from the full 23.5 years to a present value of 15.8 years. When a ten percent discount is applied the present value of the life years is reduced further to 8.9 years. This analysis considers the proposal over twelve years rather than the full 23.5 years or when discounted at 3.5 percent 15.8 years and is therefore considered to provide a realistically basis for further calculations.

**Quality of life adjusted years**

The severity of an adverse event is quantified as a preference score of one where the event has no negative health impacts, to a score of zero for death. The Australian burden of disease study<sup>22</sup> preference score for the average weight across all injury sequelae resulting from adverse drug events is defined as 0.547.

A change in QALYs is defined as one minus the preference score, times the duration of the event in years. Clearly, an adverse event that causes death or permanent disability will have a duration equal to the projected life expectancy of the individual

<sup>21</sup> Statistics New Zealand. *New Zealand Life Tables 2000-2002*.

<sup>22</sup> Mathers C, Vos T, Stevenson C 1999. The burden of disease and injury in Australia. AIHW cat. no. PHE 17. Canberra: AIHW.

subject to the medication error. For this analysis other disabilities are defined as lasting 26 or two weeks respectively. Table 6 shows the quality of life scores used to calculate the quality adjusted life years (Table 7).

**Table 6: Derivation of Quality of Life weights**

Type of Adverse Drug Event (ADE)	Preference Score	Change in QALY	Duration	QOL weight
ADEs each year resulting in <b>death</b>	0.000	1 - 0.000	Permanent	1.000
ADEs each year resulting in <b>permanent disability</b>	0.547	1 - 0.547	Permanent	0.453
ADEs each year resulting in <b>disability lasting between 1-12 months</b>	0.547	1 - 0.547	26 weeks (0.5 years)	0.227*
ADEs each year resulting in <b>disability lasting less than 1 month</b>	0.547	1 - 0.547	2 weeks (0.04* weeks)	0.017*

\* rounding

Table 4 provides an estimate of the lives saved and disabilities prevented through the introduction of bedside verification using barcode medication at the point of patient care. Over the twelve years of the analysis, it is projected that nearly 1,051 lives could be saved; nearly 2,813 people would have avoided permanent disability; and about another 28,600 people would not have been subject to temporary disabilities. The numbers above assume that bedside verification will reduce preventable adverse drug events by at least 65 percent. If the initiative reduces the incidence of medication error further (for example 86 percent as indicated in some United States studies) then over **3,500 lives could be saved, nearly 10,000 permanent disabilities, and close to 100,000 temporary disabilities prevented.** Alternatively, if the reduction is reduced to a 29 percent reduction then there is not net financial benefit and obviously a reduced number of lives saved or injuries prevent (see sensitivity analysis).

Using the quality of life weights from Table 6 the total number of QALYs saved can be assessed (once again assuming a 65 percent reduction in ADEs attributable to bedside verification). Over the twelve years, about 21,800 QALYs could be saved or 16,200 QALYs when discounted at 3.5 percent (Table 8).

**Table 8: Present value of QALYs saved, total costs and the cost (saving) per QALY from a 65 percent reduction in ADEs due to BPOC**

Present Value						
	Discount rate	3.5%		0.0%	5.0%	10.0%
PV QALYs saved	PV	16,180		21,766	14,329	9,779
Total cost (PV, \$M)	Gross	\$101.33		\$115.91	\$95.68	\$81.13
	Net	<b>-\$120.70</b>		<b>-\$165.57</b>	<b>-\$105.68</b>	<b>-\$68.34</b>
Cost per QALY	Gross	\$6,244		\$5,325	\$6,677	\$8,296
	Net	<b>-\$7,460</b>		<b>-\$7,607</b>	<b>-\$7,375</b>	<b>-\$6,989</b>

**Cost per QALY**

Table 8 above summarises present value of QALYs saved, total cost (both gross and net) and the cost per QALY. The gross present value cost per discounted QALY is \$6,244 and the net present value saving per discounted QALY is \$7,460. This means that there is in addition to the patient benefits a net financial saving to society, DHBs and the health sector from implementing bedside verification using BPOC and associated systems.

**Table 7: Benefits and QALYs saved**

	Project Years	Implementation				Outyears							
		1	2	1	2	3	4	5	6	7	8	9	10
<i>% implemented</i>		25%	75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
<i>% of benefits realised</i>		13%	63%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
<b>BENEFITS</b>													
ADEs each year resulting in <b>death</b>		8	61	98	98	98	98	98	98	98	98	98	98
ADEs each year resulting in <b>permanent disability</b>		21	164	263	263	263	263	263	263	263	263	263	263
ADEs each year resulting in <b>disability lasting between 1-12 months</b>		31	247	396	396	396	396	396	396	396	396	396	396
ADEs each year resulting in <b>disability lasting less than 1 month</b>		178	1,423	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277
ADEs each year with <b>undefined impact</b>		10	83	133	133	133	133	133	133	133	133	133	133
<b>QALYs GAINED</b>													
	<i>QOL Weight</i>												
Deaths prevented	<i>1.000</i>	8	69	167	265	363	462	560	658	756	854	952	1051
Permanent disability prevented	<i>0.453</i>	9	84	203	322	441	560	679	798	917	1036	1155	1274
Disability lasting between 1-12 months prevented	<i>0.227</i>	7	63	153	242	332	422	511	601	691	780	870	960
Disability lasting less than 1 month prevented	<i>0.017</i>	3	28	68	107	147	187	226	266	306	345	385	425
<b>Total QALYs gained per annum</b>		<b>27</b>	<b>244</b>	<b>590</b>	<b>937</b>	<b>1283</b>	<b>1630</b>	<b>1976</b>	<b>2323</b>	<b>2669</b>	<b>3016</b>	<b>3362</b>	<b>3709</b>

## **SENSITIVITY ANALYSIS**

The robustness of any analysis depends on the sensitivity of variables and the assumptions used. As described above this analysis is not intended to be definitive as consultation, planning, and tendering are likely to change features, costs and cost offsets. The sensitivity analysis below considers;

- effectiveness of reducing adverse drug events
- life years saved per event
- quality of life weight
- length of stay
- cost offset associated with hospital costs per day

### **Effectiveness of reducing adverse drug events**

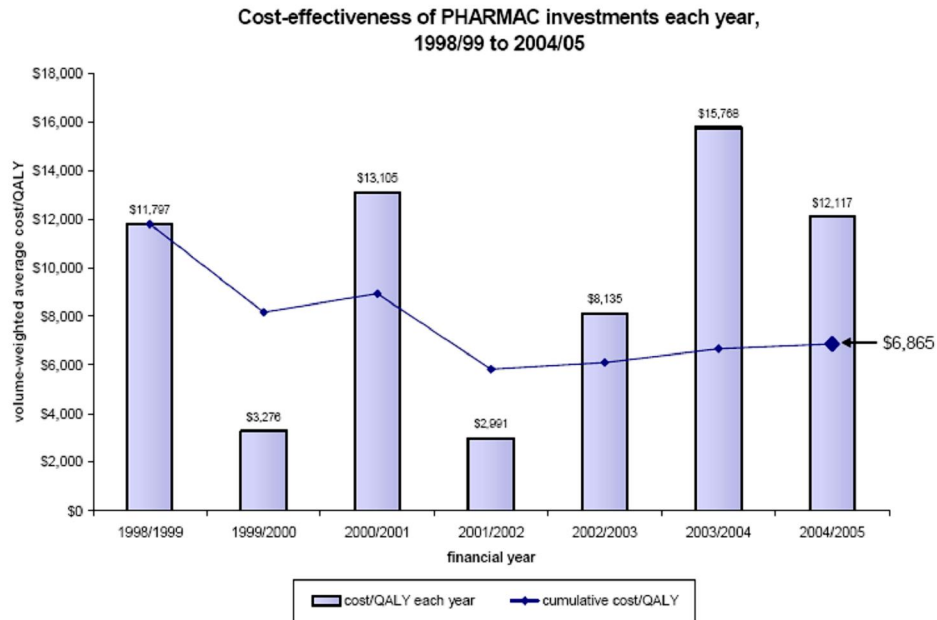
The value of the proposed investment depends critically on the reduction in adverse drug events. Studies of the implementation of bedside verification in hospitals using barcoded drugs range between 65-86 percent reduction in medication errors.

Table 10 presents a range of values for the reduction due to bedside verification ranging from 10 percent to 86 percent. As shown below, the net saving resulting is relatively insensitive in the range 86-50 percent. The threshold, where net savings are zero occurs is when the intervention reduces adverse drug events by 29 percent. At this point the gross cost per discounted QALY is nearly \$14,000 and the net cost per QALY is saving of about \$774. By way of comparison, the figure below shows cost per QALY of Pharmac investments and this in 2004/05 this was an average average cost of \$12,117 (see Figure 1). As presently proposed, the bedside verification proposal would have a gross cost of around \$6,244 per discounted QALY and when offsets are taken into account a net saving per QALY of around \$7,460. This saving compares very well to investment decisions made by Pharmac which have a net cost rather than saving. When compared on the same basis of cost per QALY with Pharmac investments the bedside verification proposal is less expensive by about \$20,000 per QALY.

It can be argued that the 65 percent reduction does not account accurately for the difference between preventable and non-preventable adverse drug events. As described in Appendix A to the consultation document, some adverse reactions to medications occur, not because of error, but because of the way people metabolise some medications or due to unknown allergies. These events are defined as non-preventable. At this time there are no systems (that includes BPOC) that can identify or prevent these potential events. Recalling the definition provided in the beginning of this report, a medication error only relates to preventable events.

Quantifying the extent of the medication error rate is problematic, not the least because of the limited number and size of studies in New Zealand. However, without conducting further studies – Measuring the

Figure 1: Cost-effectiveness of PHARMAC investments each year, 1998/99 to 2004/05



### Life years saved per event

As described above, the average age of patients identified in the NZQHS review as having been subject to medication error is 58.6 years<sup>23</sup> and these patients would have a weighted average life expectancy of 23.5 years. When discounted planning purposes at 3.5 percent, this life expectancy decreases to 15.8 years. The cost utility analysis considers costs and benefits of the proposal over only the first two years of implementation and first ten years of operation. As shown in Table 10, varying the life expectancy from 23.5 years to ten years does not materially change the gross cost or net saving per QALY.

It could be argued that patients who need hospital based attention will have a reduced life expectancy, after all, the reason they are in hospital is because they are seriously ill. In fact, the NZQHCS report noted that adverse events were disproportionate among patients over 65. If a life expectancy of five years is used the gross costs are about \$8,770 per discounted QALY and the net saving rises to about \$10,500 per discounted QALY.

As shown in Table 10, the overall cost is not very sensitive to this parameter it is believed that assessing the costs and benefits over a twelve year period is appropriate.

<sup>23</sup> Briant, R., Wasan, A., Lay-Yee, R., and Davis, P., 2004: Representative case series from public hospital admissions 1998: drug and related therapeutic adverse events. *New Zealand Medical Journal*, v 117, 1188 p8.

**Quality of life weight**

The Australian Burdon of Disease study defines a preference score of 0.547 across the full range of disabilities caused by adverse drug events. A change in the preference score will influence the present value of QALYs and therefore the cost/saving per QALY. Table 11 compares preference scores of 0.800 and 0.000 against the Burdon of Disease value and provides the gross and net cost per QALY as well as the present value of the QALYs. As described earlier, a preference score of one indicates no impact while a patient dying would result in a score of zero.

**Table 9: Sensitivity of Quality of Life weight on permanent disability and other temporary disabilities**

QOL weight, disability	Preference score	PV QALYs	Cost per QALY	
			Gross	Net
Lower	0.800	12,808	\$7,888	-\$9,424
Burdon of disease study	0.547	16,180	\$6,244	-\$7,460
Upper	0.400	18,139	\$5,569	-\$6,654
Maximum	0.000	23,471	\$4,304	-\$5,142

At the extremes of the preference score (0.800 and 0.000) there is a difference of over 10,000 QALYs, gross costs per QALY of \$3,584 and net savings per QALY of \$4,282. Using a preference score for all disabilities of zero suggests no impact from the ADE or at 0.800 the impact was severe. Given the range on consequences likely from an adverse drug event it is believed that these extremes are not a valid measure for the average measure.

The change in the present value of QALY for ADE resulting in disability indicates that the calculation is not sensitive to changes in preference score. This is because of the strong influence exerted by patient deaths on QALYs and the cost offset of reduced bed days. There are net savings over the range of preference scores indicating that the proposal is not sensitive to variation in quality of life preference scores and that the proposal would improve health and save money for the health sector.

**Length of stay**

The largest cost offset is the reduction in extra days of hospital stay attributable to an adverse drug event. This sensitivity analysis uses an average from the NZQHS research of 7.4 days per event and compares this with results using ten, 7.5, and 2.5 days of extra stay (Table 10). If the longer attributable stay of 10 days is used the saving per QALY of about \$11,700 could be achieved. If only a reduction of 5 days is achieved the proposal still produces a saving of around \$3,200 per QALY (or \$5,200 per ADE). The threshold for no net saving resulting from reducing the length of stay is about 3.3 days. That is that if the proposal resulted in a 3.3 day reduction in average length of stay then there would be no net financial saving.

As noted above, the major cost off-set is from reducing the number of patient days attributable to adverse drug event. While the cost utility is sensitive to the assumptions in this area, the gross saving that could be achieved remain positive over the range considered and as shown in Figure 1 the saving resulting from compares very well to investment decisions of PHARMAC.

### **Cost offset associated with hospital costs per day**

As described above, the main cost offset comes from preventing patients needing extra days of hospital stay because they have been subject to adverse drug events and that the analysis uses a cost per day of \$1,031 (total hospital costs divided by number of inpatient days). The current 2005/06 diagnostic related group (DRG) value is \$2,647 per day. As described above this price is based on the Victorian cost weights (Wies8) modified by the Ministry of Health for derived 2004/05 contracted prices with DHBs. Price excludes the cost of adjusters paid to DHBs for complexity (tertiary), diseconomies of scale, M ori health, capital adjustment, acute demand and blood. DRG cost is an average of all procedures performed in a hospital. It is assumed that the majority of additional days of hospital stay would be recuperative and therefore that the DRG cost is likely to be high. On that basis, the cost per day of \$1031 is believed to better reflect the actual costs to a DHB.

As Table 10 shows below, the threshold cost per day is about \$459. So if the cost to the DHB of caring for a patient was \$459 per day there would be no net saving. Despite this, there is still a saving for each adverse drug event.

**Table 10: Sensitivity of changing effectiveness of reducing ADEs, life years per event, benefit associated with decreasing length of stay and cost of each days of hospital stay.**

Effectiveness in reducing ADEs	Effectiveness	Annual events prevented		QALYs saved	Total cost (PV, \$m)			PV cost per discounted QALY	
		Deaths	Disabilities		PV	Total cost (PV, \$m)		Gross	Net
						Gross	Net		
Central value	65%	98	263	16,180	\$101	-\$121	\$6,244	-\$7,460	
Upper	85%	130	348	21,407	\$101	-\$188	\$4,719	-\$8,767	
50%	50%	76	202	12,446	\$101	-\$73	\$8,117	-\$5,853	
33%	33%	50	133	8,214	\$101	-\$19	\$12,299	-\$2,268	
Threshold	29%	44	117	7,196	\$101	-\$6	\$14,020	-\$774	
10%	10%	15	40	2,489	\$101	\$55	\$40,586	\$21,989	

Life years per event		Annual events prevented		QALYs saved	Total cost (PV, \$m)			PV cost per discounted QALY	
		Deaths	Disabilities		QALYs	Total cost (PV, \$m)		Gross	Net
						Gross	Net		
Central value	23.5	98	263	16,180	\$101	-\$121	\$6,244	-\$7,460	
Sick patients	10	98	263	16,019	\$101	-\$121	\$6,307	-\$7,535	
Sicker patients	5	98	263	11,519	\$101	-\$121	\$8,770	-\$10,478	

Length of stay	Days saved	Annual events prevented		QALYs saved	Total cost (PV, \$m)			PV cost per discounted QALY		Savings per ADE
		Deaths	Disabilities		QALYs	Total cost (PV, \$m)		Gross	Net	
						Gross	Net			
Central value	7.5	98	263	16,180	\$101	-\$121	\$6,244	-\$7,460	\$7,733	
High	10	98	263	16,180	\$101	-\$190	\$6,244	-\$11,731	\$10,310	
Low	5	98	263	16,180	\$101	-\$52	\$6,244	-\$3,188	\$5,155	
Threshold	3.3	98	263	16,180	\$101	-\$6	\$6,244	-\$344	\$3,439	

Hospital cost /day	Cost /day	Annual events prevented		QALYs saved	Total cost (PV, \$m)			PV cost per discounted QALY		Savings per ADE
		Deaths	Disabilities		QALYs	Total cost (PV, \$m)		Gross	Net	
						Gross	Net			
Central value (Ministry avg)	\$1,031	98	263	16,180	\$101	-\$441	\$6,244	-\$10,704	\$7,733	

## Cost Utility Analysis

DRG	\$2,647	98	263	16,180	\$101	-\$1,424	\$6,244	-\$34,544	\$22,118
Threshold	\$170	98	263	16,180	\$101	-\$1	\$6,244	-\$3	\$1,275

**APPENDIX A: SUPPORTING INFORMATION**

**Medication error rates reported in various studies**

	Study	Definition of Medication Error Used	Medication Error Rate		Medication Error Location	Medication Error Prevention
A	Barker, Flynn, Pepper, et al. (2002)	Medication error defined as a dose administered differently than as ordered on the patient's medical records	Overall error rate 19% of doses. Breakdown Wrong time 43%, omission 30%, wrong dose 17% unauthorised drug 4%  7% were judged as potential adverse drug events	Prospective cohort study using stratified random sample from 36 institutions. Medication errors were witnessed by observation, and verification by a research pharmacist. Clinical significance was judged by an expert panel	Prescribing  Drug administration	
A	Bates et al. (1995)	ADE - Adverse drug event+defined as an injury resulting from medical intervention related to a drug.	6.5% of admissions (1,891,982)	Nested case-control study within a prospective cohort study of 4108 admissions to a stratified sample of 11 medical and surgical units in two tertiary-care hospitals over a six month period	Prescribing, transcribing, dispensing and administration	28% (529,755)
A	Briant et al. (2004)	Part of the NZQHS. Adverse events (AEs) defined as operative, system, drug, therapy, diagnosis, procedure and other+	850 AEs	Two stage retrospective study of 6579 medical records randomly sampled from admissions for 1998 in 13 generalist hospitals providing acute care	15.4% of AEs (drug incidents) 7.3% of AEs (therapeutic incidents)	Highly preventable drug events 43.9%

## Cost Utility Analysis

A	Classen et al. (1997)	ADE	2.43% of admissions (total sample 698,578; 1580 cases and 20197 controls)	Systematic evaluation of every third prescribing error detected and averted by pharmacists in a 631-bed tertiary care teaching hospital between July 1, 1994, and June 30, 1995. Each error was concurrently evaluated for the potential to result in adverse patient consequences. Each error was retrospectively evaluated by a physician and 2 pharmacists and a factor likely related to the error was identified.	Prescribing, transcribing, dispensing and administration	49% (342,303)
A	Davis et al. (2001)	Broad study (NZQHCS) looking at adverse events with ADEs as a subset	850 AEs 12.9% of all admissions are drug related	Two stage retrospective study of 6579 medical records randomly sampled from admissions for 1998 in 13 generalist hospitals providing acute care	Operative 24.3%; system 24%; drug 12.9%; therapy 8.4% diagnosis 8%; procedure 7.7%; other 15.3%.	Highly preventable 37.1%
A	Dean, B., Schachter, M., Vincent, C., and Barber, N., 2002. Prescribing errors in hospital inpatients: their incidence and clinical significance. <i>Quality Safety in Health Care</i> ; v11 p3940-344.	Prescribing error	36,200 records	Pharmacists prospectively recorded details of all prescribing errors in non-obstetric inpatients during a four week period	1.5% error in prescribing, 0.4% potentially serious: 54% choice of dose	
A	Folli, Poole, Benitz at al. (1987)	Errant medication order considered to be an order that was not in	Between 4.9 and 4.5 errors per 1,000 orders		Verbal medication error (lowest rate); computerized medication error rate	N/A

## Cost Utility Analysis

		accordance with standard pediatric references, current published literature, or dosing guidelines approved by the hospital's pharmacy and therapeutics committees.			(6.3 per 1000); handwritten medication error rate.	
<b>A</b>	<b>Jha et al. (1998)</b>	<b>ADE</b>	<b>4.1% of admissions</b>	<b>(1,193,404)</b>	<b>Prescribing, transcribing, dispensing and administration</b>	<b>27% (322,219)</b>
A	Kaushal et al. (2001) .	%Medication Error+ defined as errors in drug ordering, transcribing, dispensing, administering, or monitoring.	5.7%	Cohort study of 1120 patients admitted to 2 academic institutions during a 6 week period Review of 10,778 medication orders	N/A	Reviewers judged that CPOE could have prevented 93% of events
A	Lawton et al (2005)	Documented potential errors over 9 months following implementation of BPOC	15.8%	1,438 patient admissions;		aggregate error rate 15.8%, Consisting of 48% wrong dose, 15% no order, 15% wrong patient, 11% wrong form, 7% wrong time, 7% wrong drug.
A	Leape et al. (1991)	%Adverse event+ defined as unintended injury caused by medical management and resulted in measurable	18%	review of 30,195 randomly selected hospital records	Wrong drug treatment	N/A

		disability.				
A	Leape et al. (1995) breakdown on same data as Bates et al 1995	ADE	Ordering 39% Administering 38% Transcribing 12% Dispensing 11%	All admissions to 11 medical and surgical units in two tertiary care hospitals over 6 months.		N/A
A	Lesar et al. (1990 and 1997)	N/A	3.13 errors per 1,000 orders	Systematic evaluation of every third prescribing error detected and averted by pharmacist in a 631 bed tertiary care teaching hospital during a one-year period. 28,411 medication orders written	Prescribing error detected and averted	N/A
A	Phillips, Christenfeld, Glynn (1998)	Medication errors defined as %accidental poisonings by drugs, medicaments, and biologicals+ and resulting from %acknowledged errors, by patients or medical personnel.+	1 out of 439, outpatient deaths and 1 out of 1622, inpatient deaths (1983); 1 out of 131, outpatient deaths and 1 out of 854, inpatient deaths (1993).	Examination of all US death certificates between 1983 and 1993	N/A	
A	Raschke et at 1998	ADE prevented using computer alert	64 events per 1000 patients	9306 non-obstetric patients over 6 month period		
A	Senst et al.(2001)	ADE	4.2% during hospitalisation, 3.2% of admissions caused by ADE admissions (1,222,511)	Daily record review of a random patient sample over 53 days of ADEs occurring after or causing admission to a four hospital integrated academic health network	Prescribing, transcribing, dispensing and administration	15% (183,377)
A	Wiffen et al (2002)	Adverse drug reaction (an event that is noxious and	7% of patients or admissions	Literature review of 108 primary studies involving 412,000 patients		

		unintended and occur at doses in humanō This definition excludes intentional or deliberate overdose or drug abuse)				
	<b>AIM Global, Bar Codes in Hospitals: Unit Dose and Beyond</b>	<b>Medication errors as any deviation from the following route: “proper medication means that the right medication in the right dose via the right route is administered at the right time to the right patients.”</b>	<b>N/A</b>		<b>Medication, administration, record</b>	<b>30% (eMAR)</b>
<b>C</b>	<b>Allen, Barker (1990) in: Schneider (2003)</b>	<b>Errors described as “deviations from the physician order”</b>	<b>10%+ (traditional system)</b>		<b>Medication administration</b>	<b>1.9% and 3.5% (unit dose system)</b>
<b>C</b>	<b>Bates et al. (1998) in: Kinninger, Kelly (2003)</b>	<b>N/A</b>	<b>N/A</b>		<b>N/A</b>	<b>55%</b>
	<b>Beates, Boyle, Vander Vliet et al. (1995) –</b>	<b>“Medication Error” defined as errors in the process of ordering or delivering medication, regardless of whether an injury</b>	<b>5.3%</b>	<b>Review of 10,070 medication orders to identify medication errors</b>	<b>N/A</b>	<b>N/A</b>

		occurred or the potential for injury was present.				
	Classen et al. (1997) – Matched-case control study of all patients admitted to a hospital in a three-year period	“Adverse drug event” defined as an event that is “noxious and unintended and occurs at doses used in humans for prophylaxis, diagnosis, therapy, or modification of physiologic functions” but excludes therapeutic failures, poisonings, and intentional overdoses.	1%		N/A	50%
	West, Levine, Magram et al. (1994) -	N/A	N/A	Study of 18,262 medication and intravenous fluid orders given in a three-month period at a children hospital	N/A	N/A
	Grasha and Schell (2002), Psychological Factors, Workload and Risk of Medication Errors,	Medication errors	N/A		N/A	95%
	Porter, Jick (1977)	“Suspected	0.02%	Survey of 26,462 patients in	N/A	N/A

		adverse reactions” defined as any undesired or unintended effect of a drug.		seven countries		
	Thur (1972)	Wrong drug or solution; wrong dosage of a drug or solution volume; an unordered or discontinued drug; or two or more pharmaceutically incompatible drugs in the same admixture.	21%		N/A	N/A
B	Webster, Merry, Larsson, McGrath, Weller (2001) .	Drug administration error	Drug administration error in anaesthesia 0.0075%  1 error for every 133 anaesthetics	Survey of frequency and nature of drug administration errors in anaesthesia at Auckland and Wellington hospitals	Incorrect doses: 20% Substitutions: 20% Omissions; Repetition/Insertions ; Incorrect route.	N/A
C	Eastern Research Group (ERG) (2003),	Summary of other published reports on ADE	4.3% of admissions		Prescribing, transcribing, dispensing and administration	50%

**Improvement rates following BPOC introduction**

Class*	Study	Definition of Medication Error Used	Medication Error Rate	Medication Location	Error	BCPC Improvement rate
A	Bates et al. (1998)	Randomized comparison between CPOE and the combination of CPOE plus team intervention. 726 bed tertiary care hospital over 6 months (phase 1 and 2491 admissions) and 9 months (phase 2 and 4220 admissions)		Introduction of CPOE		Non-intercepted serious medical errors decreased 55% Preventable ADE declined 17%, non-intercepted potential ADEs declined 84%
A	Bates et al. (1999) (uses data from Bates et al 1998)	A	Bates (2000) Using Information Technology to Reduce rates of Medication Errors in Hospitals, British Medical Journal 320:788-791.	N/A		N/A
A	Coyle, Heinen (2005) Evolution of BCMA within the Department of Veteran Affairs	Medication errors	N/A	N/A		23% (1 <sup>st</sup> year)

\* **Class A:** Primary sources (large sample academic studies)

**Class B:** Summary papers, papers relying on Class A Papers findings

**Class C:** Secondary Sources (newspaper articles, newsletters, miscellaneous articles)

\*\* Mean value not part of the original study by Larrabee and Brown. Author's addition for the purpose of following evaluations.

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					66% (after 5 years)
A	Glare (2006)	Reduction in error after implementation of BPOC system Observed 115,164 dispensed doses before and 253,983 after			90% reduction in rates of target dispensing error
A	Johnson et al. (2002)	Medication errors reduction following introduction of BCMA using averted errors recorded by BCMA system	75.% 93%	Medication/administration incorrect dose Wrong patient, missed medication	86.2% improvement over pre-implementation  (75.47% wrong medication; 61.97% incorrect dose; 93.48% wrong patients errors; 87.41% wrong time; 70.3% missed medications)
A	Johnson, Carson, Tucker, Willett (2005) VAMA, quoted in: Evolution of BCMA within the Department of Veteran Affairs	Medication errors	N/A	N/A	86%  (equaling to 594,000 errors prevented between 1995 and 2001)
A	Kelly (2005)	Medication error from 6 sites reporting 16,633 clinically significant saves across the 6 sites during a period of 6 months			Wrong time 51% Wrong dose 28% Wrong med 18% Wrong route 1.8% Wrong patient 0.8% other
A	Larrabee and Brown (2003)	Medication error reduction following implementation of	N/A	N/A	71% - 86%

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		BPOC in a 148 bed pilot at Northern Michigan Hospital			(78.5% mean)** Reported ADE 12, prevented ADEs using BPOC 187 Wrong drug 15% Wrong dose 18% Not due 7% Discontinued 60%
A	Malcolm, Carlson, Tucker, Willette (1999)	N/A	N/A	N/A	100% in 5-years  (equaling to 378,000 medication errors prevented)
A	Poon et al (2006)	735-bed tertiary hospital 115,164 pre-implementation and 253,984 post implementation	Pre implementation	Medication dispensing	93 to 96% relative reduction in the incident of target dispensing errors and 86 to 97% relative reduction in the incidence of potential ADE
A	Puckett F (1995)	326 bed North Colorado Medical centre following implementation of a point of care system		Pre-implementation Wrong drug 33% wrong time 43% dose omitted 52%	Pre - 0.17% per doses administered  Post 0.07% per doses administered  71% improvement  (1992-1994)
A	Ragan et al (2005)	Retrospective study following implementation of		Dispensing error	96% reduction in dispensing errors;

		BCMA system into a 640 bed and 102 bassinets at Wesley Medical centre			from 42 errors per week to 1.8 errors
A	Sakowski et al (2005)	Introduction of bar-code medication administration system into 27 not-for-profit community hospitals in Northern California	Retrospective audit of 17,025 warning and error reports generated by a BPOC system,		Errors prevented 47% dose significantly early; 27% no order; order discontinued; 7% no order patient specific med; 2% wrong route; 7% other
A	Schwarz, Brodowy (1995)	Dispensing errors	N/A	Dispensing	96%
B	Thielke (2003) in Schneider (2003) .	Medication errors review by the University of Wisconsin Hospital following BCMA implementation	9.09% (baseline error rate pre-BCMA)	Overall medication error rate reduction  Wrong dose; Wrong dosage form; Omitted doses; Wrong time; Wrong drug.	87% (post-BCMA reduction)  100% 100% 92% 77% 51%
B	Agency for Healthcare Research and Quality, Reducing and Preventing Adverse Drug Events to Decrease Hospital Costs	Adverse drug event (ADE)	770,000 injuries per year	N/A	28% - 95%
B	Anderson, Jensen (2000) Management Case Study; in: Kelly (2005) <sup>24</sup>	Medication errors	N/A	N/A	59%
B	Grotting et al. (2002) The Effect of Barcode-Enabled Point-of-Care Technology on Patient Safety	Medication errors	N/A	Medication administration	65% - 74%
B	Harry and Lowe (2004) in: Kelly (2005) <sup>25</sup>	Medication errors	N/A	Medication administration	54%

<sup>24</sup> Original paper not sighted

B	HIMSS (2003) Implementation Guide for the Use of Bar Code Technology in Health Care	ADE	39% 12% 11% 38%	Ordering; Order verification; Preparation/dispensing; Administration	65% - 86% (1995-2002)  86% is from VA hospitals
B	Joint Commission for the Accreditation of Healthcare Organisations (2003) National Patient Safety Goals	Medication errors	N/A	N/A	86%
B	<b>Malcolm at al. (1999); Yang et al., 2001; Brown (2002); Rough (2002); and Churchill (2002).</b>	<b>ADE</b>	<b>1.25M ADEs p/y in the US (372,000 preventable)</b>	<b>Dispensing, administration</b>	<b>70%- 80%,</b>
B	Neuenschwander et al. (2003)	Summary of other papers on medication errors and improvement when BPOC introduced	N/A	N/A	65% - 86%
B	Rough (2000)	Medication errors	N/A	N/A	87%
B	Kininger and Kelly (2003)	Summary paper on medication errors reduction following introduction of BPOC	N/A	N/A	67% - 86%
B	Wright, Katz (2005) Bar Coding for Patient Safety, The New England Journal of Medicine, 335;4	ADE	N/A	Medication	50% +
C	Attract and Retain RNS, Modern Healthcare, Legislation and Regulation, January 31, 2000	Medication errors	N/A	N/A	71%
C	American Society of Health-System Pharmacists, Patient Concern: National Survey Research Report	Medication errors	N/A	N/A	67%

<sup>25</sup> Ibid.

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	(1999)				
C	Information Technology: Medication Errors Reduced by 87% with New Tool, Drug Week, December 20, 2002	Medication errors	N/A	N/A	87%
C	Willis, transcript from: Public Hearing: Bar Coding . A Regulatory Initiative	N/A	N/A	Medication, incorrect dose, wrong patient, missed medication	86.2% (1993 - 2001)  (75.5% in wrong medication errors; 93.5% in incorrect dose errors; 87.4% in wrong patients errors; 70.3% in missed medications)

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## **General notes**

1. Class A+ papers include primary sources. These studies have been identified, selected and validated on the following grounds:
  - original figures resulting from major studies;
  - data resulting from large-scale case studies;
  - statistics provided by most prominent academics in the field;
2. Class B+ papers represent summaries and elaborations of Class A studies. The statistics provided rely on the original findings and have not been validated.
3. Class C+ papers include newspaper articles, newsletters and other material from secondary sources.
4. The validation process relating to the 65% to 86% BCPC reduction rate relies solely on Class A findings.

## **Class A: range and median**