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Five-Hundred Life-Saving Interventions and Their Cost-Effectiveness

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We gathered information on the cost-effectiveness of life-saving interventions in the United States from publicly available economic analyses. "Life-saving interventions" were defined as any behavioral and/or technological strategy that reduces the probability of premature death among a specified target population. We defined cost-effectiveness as the net resource costs of an intervention per year of life saved. To improve the comparability of cost-effectiveness ratios arrived at with diverse methods, we established fixed definitional goals and revised published estimates, when necessary and feasible, to meet these goals. The 587 interventions identified ranged from those that save more resources than they cost, to those costing more than 10 billion dollars per year of life saved. Overall, the median intervention costs $42,000 per life-year saved. The median medical intervention costs $19,000/life-year; injury reduction $48,000/life-year; and toxin control $2,800,000/life-year. Cost/life-year ratios and bibliographic references for more than 500 life-saving interventions are provided.

KEY WORDS: Cost-effectiveness; economic evaluation; life-saving; resource allocation.

1. INTRODUCTION

Risk analysts have long been interested in strategies that can reduce mortality risks at reasonable cost to the public. Based on anecdotal and selective comparisons, analysts have noted that the cost-effectiveness of risk-reduction opportunities varies enormously, often over several orders of magnitude.(1–5) This kind of variation is unnerving because economic efficiency in promoting survival requires that the marginal benefit per dollar spent be equal across investments.

Despite continuing interest in cost-effectiveness, we could find no comprehensive and accessible data set on the estimated costs and effectiveness of risk management options. Such a dataset could provide useful comparative information for risk analysts as well as practical information for decision makers who must allocate scarce resources. To this end, we report cost-effectiveness ratios for more than 500 life-saving interventions across all sectors of American society.

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2. METHODS

2.1. Literature Review

We performed a comprehensive search for publicly available economic analyses of life-saving interventions.

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"Life-saving interventions" were defined as any behavioral and/or technological strategy that reduces the probability of premature death among a specified target population. To identify analyses we used several on-line databases, examined the bibliographies of textbooks and review articles, and obtained full manuscripts of conference abstracts. Analyses retained for review met the following three criteria: (1) written in the English language, (2) contained information on interventions relevant to the United States, and (3) reported cost per year of life saved, or contained sufficient information to calculate this ratio. Most analyses were scientific journal articles or government regulatory impact analyses, but some were internal government memos, reports issued by research organizations, or unpublished manuscripts.

Two trained reviewers (from a total of 11 reviewers) read each document. Each reviewer recorded 52 items, including detailed descriptions of the nature of the life-saving intervention, the baseline intervention to which it was compared, the target population at risk, and cost per year of life saved. The two reviewers worked independently, then met and came to consensus on the content of the document.

Approximately 1200 documents were identified for retrieval. Of these 1200 documents, 229 met our selection criteria. The 229 documents contained sufficient information for reviewers to calculate cost/life-year saved for 587 interventions.

2.2. Definitional Goals

To increase the comparability of cost-effectiveness estimates drawn from different economic analyses, we established seven definitional goals. When an estimate failed to comply with a goal, reviewers attempted to revise the estimate to improve compliance.[8] In general, reviewers used only the information provided in the document to revise estimates. The seven definitional goals were:

1. Cost-effectiveness estimates should be in the form of "cost per year of life saved." Cost/life saved estimates should be transformed to cost/life-year by considering the average number of years of life saved when a premature death is averted.
2. Costs and effectiveness should be evaluated from the societal perspective.
3. Costs should be "direct." Indirect costs, such as foregone earnings, should be excluded.
4. Costs and effectiveness should be "net." Any resource savings or mortality risks induced by the intervention should be subtracted out.[9]
5. Future costs and life-years saved should all be discounted to their present value at a rate of 5%.
6. Cost-effectiveness ratios should be marginal or "incremental." Both costs and effectiveness should be evaluated with respect to a well-defined baseline alternative.
7. Costs should be expressed in 1993 dollars using the general consumer price index.

2.3. Categorization

Interventions were classified according to a four-way typology. (1) Intervention Type (Fatal Injury Reduction, Medicine, or Toxin Control), (2) Sector of Society (Environmental, Health Care, Occupational, Residential, or Transportation), (3) Regulatory Agency (CPSC, EPA, FAA, NHTSA, OSHA, or None), and (4) Prevention Stage (Primary, Secondary, or Tertiary).

Interventions we classified as primary prevention are designed to completely avert the occurrence of disease or injury; those classified as secondary prevention are intended to slow, halt, or reverse the progression of disease or injury through early detection and intervention; and interventions classified as tertiary prevention include all medical or surgical treatments designed to limit disability after harm has occurred, and to promote the highest attainable level of functioning among individuals with irreversible or chronic disease.[(6)]

3. RESULTS

Cost-effectiveness estimates for more than 500 life-saving interventions appear in Appendix A. This table is separated into three sections according to the type of intervention: Fatal Injury Reduction, Toxin Control, and Medicine. The first column of Appendix A contains the reference number assigned to the document from which the cost-effectiveness estimate was drawn (references are in Appendix B.) The second column contains a very brief description of the life-saving intervention. The

[8] Appendices describing the cost-effectiveness formulas used to operationalize these definitional goals, along with some examples of the calculations made by reviewers of the economic analyses, are available from Dr. Tengs.

[9] If savings exceed costs, the result could be negative, so that the cost-effectiveness ratio might be ≤$0.

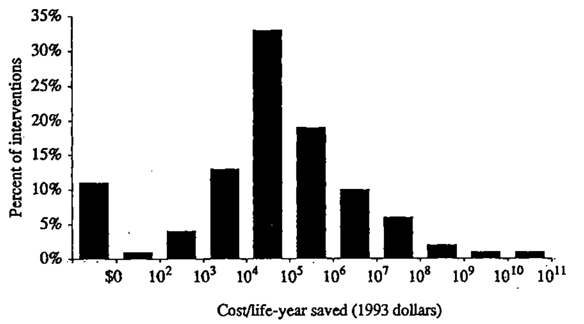

Fig. 1. Distribution of cost/life-year saved estimates (n = 587).

baseline intervention to which the life-saving intervention was compared appears parenthetically as "(vs. __)" when the author described it. The last column of Appendix A contains the cost per year of life saved in 1993 dollars.

As shown in Fig. 1, these interventions range from those that save more resources than they consume, to those costing more than 10 billion dollars per year of life saved. Furthermore, variation over 11 orders of magnitude exists in almost every category.

In addition to the large variation within categories, variation in cost-effectiveness also exists between categories. As summarized in Table I, while the median intervention described in the literature costs $42,000 per life-year saved (n = 587), the median medical intervention costs $19,000/life-year ($n$ = 310); the median injury reduction intervention costs $48,000/life-year ($n$ = 133); and the median toxin control intervention costs $2,800,000/life-year ($n$ = 144).

Cost-effectiveness also varies as a function of the sector of society in which the intervention is found. For example, as shown in Table I, the median intervention in the transportation sector costs $56,000/life-year saved ($n$ = 87), while the median intervention in the occupational sector costs $350,000/life-year ($n$ = 36). Further dividing occupational interventions into those that avert fatal injuries and those that involve the control of toxins, reveals medians of $68,000/life-year ($n$ = 16) and $1,400,000/life-year ($n$ = 20), respectively.

As noted in Table II, the median cost-effectiveness estimate among those interventions classified as primary prevention is $79,000/life-year saved ($n$ = 373), exceeding secondary prevention at $23,000/life-year ($n$ = 111) and tertiary prevention at $22,000/life-year ($n$ = 103). However, if medicine is considered in isolation, we find that primary prevention is more cost-effective that secondary or tertiary prevention at $5,000/life-year ($n$ = 96).

Table I. Median of Cost/Life-Year Saved Estimates as a Function of Sector of Society and Type of Intervention

	Type of intervention			
Sector of society	Medicine	Fatal injury reduction	Toxin control	All
Health care	$19,000 ($n$=310)	N/A[a]	N/A	$19,000 ($n$=310)
Residential	N/A	$36,000 ($n$=30)	N/A	$36,000 ($n$=30)
Transportation	N/A	$56,000 ($n$=87)	N/A	$56,000 ($n$=87)
Occupational	N/A	$68,000 ($n$=16)	$1,400,000 ($n$=20)	$350,000 ($n$=36)
Environmental	N/A	N/A	$4,200,000 ($n$=124)	$4,200,000 ($n$=124)
All	$19,000 ($n$=310)	$48,000 ($n$=133)	$2,800,000 ($n$=144)	$42,000 ($n$=587)

[a] Not applicable by definition.

Table II. Median of Cost/Life-Year Saved Estimates as a Function of Prevention Stage and Type of Intervention

	Type of intervetion			
Prevention stage	Medicine	Fatal injury reduction	Toxin control	All
Primary	$5,000 ($n$=96)	$48,000 ($n$=133)	$2,800,000 ($n$=144)	$79,000 ($n$=373)
Secondary	$23,000 ($n$=111)	N/A	N/A	$23,000 ($n$=111)
Tertiary	$22,000 ($n$=103)	N/A	N/A	$22,000 ($n$=103)
All	$19,000 ($n$=310)	$48,000 ($n$=133)	$2,800,000 ($n$=144)	$42,000 ($n$=587)

The median cost-effectiveness of proposed government regulations for which we have data also varies considerably. Medians for each agency are as follows: Federal Aviation Administration, $23,000/life-year ($n$ = 4); Consumer Product Safety Commission, $68,000/life-year ($n$ = 11); National Highway Traffic Safety Administration, $78,000/life-year ($n$ = 31); Occupational Safety and Health Administration, $88,000/life-year ($n$ = 16); and Environmental Protection Agency, $7,600,000/life-year ($n$ = 89).

4. LIMITATIONS

This compilation of existing data represents the most ambitious effort ever undertaken to amass cost-effectiveness information across all sectors of society. In addition, our work to bring diverse estimates into compliance with a set of definitional goals has improved the comparability of cost-effectiveness estimates that were originally derived by different authors using a variety of methods. Nevertheless, several caveats are warranted to aid the reader in interpreting these results.

First, the accuracy of the results presented herein is limited by the accuracy of the data and assumptions upon which the original analyses were based. There remains considerable uncertainty and controversy about the cost consequences and survival benefits of some interventions. This is particularly true for toxin control interventions where authors often extrapolate from animal data. In addition, due to insufficient information in some economic analyses, reviewers were not always successful in bringing estimates into conformity with definitional goals. For example, if the original author did not report the monetary savings due to the reduction in nonfatal injuries requiring treatment, we were unable to "net out" savings, and so the costs used to calculate cost-effectiveness ratios remain gross. While some of these omissions are important, others are largely inconsequential given the relative size of cost and effectiveness estimates.

Second, the life-saving interventions described in this report include those that are fully implemented, those that are only partially implemented, and those that are not implemented at all. These interventions are best thought of as opportunities for investment. While they may offer insight into actual investments in life-saving, the cost-effectiveness of possible and actual investments are not equivalent. Work on the economic efficiency of actual expenditures is in progress.[7]

Third, this dataset may not represent a random sample of all life-saving interventions, so the generalizability of any descriptive statistics may be limited. This is because interventions that have been subjected to economic analysis may not represent a random sample of all life-saving interventions due, for example, to publication bias. That is, those economic analyses that researchers have chosen to perform and journal editors have chosen to publish may be disproportionately expensive or inexpensive. However, the statistics presented herein are certainly applicable to the 587 life-saving interventions in our dataset which by themselves comprise a vast and varied set, worthy of interest even without generalization.

Finally, we recognize that many of these interventions have benefits other than survival, as well as adverse consequences other than costs. For example, interventions that reduce fatal injuries in some people may also reduce nonfatal injuries in others; interventions designed to control toxins in the environment may have short-term effects on survival, but also long-term cumulative effects on the ecosystem; medicine and surgery may increase quantity of life, while simultaneously increasing (or even decreasing) quality of life.

5. CONCLUSIONS

This compilation of available cost-effectiveness data reveals that there is enormous variation in the cost of saving one year of life and these differences exist both within and between categories. Such a result is important because efficiency in promoting survival requires that the marginal benefit per dollar spent be the same across programs. Where there are investment inequalities, more lives could be saved by shifting resources. It is our hope that this information will expand the perspective of risk analysts while aiding future resource allocation decisions.

APPENDIX A. FIVE-HUNDRED LIFE-SAVING INTERVENTIONS AND THEIR COST-EFFECTIVENESS

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Fatal injury reduction	
	Airplane safety	
174	Automatic fire extinguishers in airplane lavatory trash receptacles	$16,000
173	Fiberglass fire-blocking airplane seat cushions	$17,000
174	Smoke detectors in airplane lavatories	$30,000
172	Emergency signs, floor lighting etc. (vs. upper lighting only) in airplanes	$54,000
	Automobile design improvements	
190	Install windshields with adhesive bonding (vs. rubber gaskets) in cars	≤ $0
52	Dual master cylinder braking system in cars	$13,000
1128	Automobile dummy acceleration (vs. side door strength) tests	$63,000
299	Collapsible (vs. traditional) steering columns in cars	$67,000
189	Side structure improvements in cars to reduce door intrusion upon crash	$110,000
52	Front disk (vs. drum) brakes in cars	$240,000
299	Dual master cylinder braking system in cars	$450,000
	Automobile occupant restraint systems	
1129	Driver automatic (vs. manual) belts in cars	≤ $0
59	Mandatory seat belt use law	$69
175	Mandatory seat belt use and child restraint law	$98
67	Driver and passenger automatic shoulder belt/knee pads (vs. manual belts) in cars	$1,300
59	Driver and passenger automatic shoulder/manual lap (vs. manual lap) belts in cars	$5,400
67	Airbag/manual lap belts (vs. manual lap belts only) in cars	$6,700
2	Airbag/lap belts (vs. lap/shoulder belts)	$17,000
56	Driver and passenger automatic (vs. manual) belts in cars	$32,000
1129	Driver airbag/manual lap belt (vs. manual lap/shoulder belt) in cars	$42,000
1129	Driver and passenger airbags/manual lap belts (vs. airbag for driver only and belts)	$61,000
59	Driver and passenger airbags/manual lap belts (vs. manual lap belts only) in cars	$62,000
68	Child restraint systems in cars	$73,000
1127	Rear outboard lap/shoulder belts in all (vs. 96%) cars	$74,000
56	Airbags (vs. manual lap belts) in cars	$120,000
1127	Rear outboard and center (vs. outboard only) lap/shoulder belts in all cars	$360,000
	Construction safety	
1137	Full (vs. partial) compliance with 1971 safety standard for concrete construction	≤ $0
1137	1988 (vs. 1971) safety standard for concrete construction	≤ $0
909	1989 (vs. no) safety standard for underground construction	$30,000
909	1989 (vs. 1972) safety standard for underground construction	$30,000
1132	1989 safety standard for underground gassy construction	$30,000
1132	Revised safety standard for underground non-gassy construction	$46,000
106	Install canopies on underground equipment in coal mines	$170,000
910	Safety standard to prevent cave-ins during excavations at construction sites	$190,000
1165	Full compliance with 1989 (vs. partial with 1971) safety standard for trenches	$350,000
1165	Full (vs. partial) compliance with 1971 safety standard for trenches	$400,000
	Fire, heat, and smoke detectors	
193	Federal law requiring smoke detectors in homes	≤ $0
13	Fire detectors in homes	≤ $0
306	Federal law requiring smoke detectors in homes	$920
19	Smoke and heat detectors in homes	$8,100
19	Smoke and heat detectors in bedroom area and basement stairwell	$150,000
303	Smoke detectors in homes	$210,000
	Fire prevention and protection, other	
122	Child-resistant cigarette lighters	$42,000
	Flammability standards	
292	Flammability standard for children's sleepwear size 0–6X	≤ $0
306	Flammability standard for upholstered furniture	$300
292	Flammability standard for children's sleepwear size 7–14	$45,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
372	Flammability standard for upholstered furniture	$68,000
12	Flammability standard for children's sleepwear size 7–14	$160,000
292	Flammability standard for children's clothing size 0–6X	$220,000
292	Flammability standard for children's clothing size 7–14	$15,000,000
Helmet promotion		
31	Mandatory motorcycle helmet laws	≤ $0
186	Federal mandatory motorcycle helmet laws (vs. state determined policies)	$2,000
175	Mandatory motorcycle helmet laws	$2,000
1006	Promote voluntary helmet use while riding All-Terrain Vehicles	$44,000
Highway improvement		
747	Grooved pavement on highways	$29,000
1105	Decrease utility pole density to 20 (vs 40) poles per mile on rural roads	$31,000
747	Channelized turning lanes at highway intersections	$39,000
747	Flashing lights at rail-highway crossings	$42,000
747	Flashing lights and gates at rail-highway crossings	$45,000
747	Widen existing bridges on highways	$82,000
1107	Widen shoulders on rural two-lane roads to 5 (vs. 2) feet	$120,000
1105	Breakaway (vs. existing) utility poles on rural highways	$150,000
1107	Widen lanes on rural roads to 11 (vs. 9) feet	$150,000
1105	Relocate utility poles to 15 (vs. 8) feet from edge of highway	$420,000
Light truck design improvements		
1091	Ceilings of 0–6000 lb light trucks withstand forces of 1.5 × vehicle's weight	$13,000
1091	Ceilings of 0–10,000 lb light trucks withstand forces of 1.5 × vehicle's weight	$14,000
1091	Ceilings of 0–8500 lb light trucks withstand forces of 1.5 × vehicle's weight	$78,000
1091	Ceilings of 0–10,000 lb light trucks withstand 5000 lb of force	$170,000
1126	Side door strength standard in light trucks to minimize front seat intrusion	$190,000
1091	Ceilings of 0–6000 lb light trucks withstand 5000 lb of force	$1,100,000
1126	Side door strength standard in light trucks to minimize back seat intrusion	$10,000,000
Light truck occupant restraint systems		
1089	Driver and passenger nonmotorized automatic (vs. manual) belts in light trucks	$14,000
834	Push-button release and emergency locking retractors on truck and bus seat belts	$14,000
1089	Driver and passenger motorized automatic (vs. manual) belts in light trucks	$50,000
1089	Driver airbag (vs. manual lap/shoulder belt) in light trucks	$56,000
1089	Driver and passenger airbags (vs. manual lap/shoulder belts) in light trucks	$67,000
Natural disaster preparedness		
1221	Soils testing and improved site-grading in landslide-prone areas	≤ $0
1221	Ban residential growth in tsunami-prone areas	≤ $0
710	Strengthen unreinforced masonry San Francisco bldgs to LA standards	$21,000
710	Strengthen unreinforced masonry San Francisco bldgs to beyond LA standards	$1,000,000
1221	Triple the wind resistance capabilities of new buildings	$2,600,000
1221	Construct sea walls to protect against 100-year storm surge heights	$5,500,000
1221	Strengthen buildings in earthquake-prone areas	$18,000,000
School bus safety		
1124	Seat back height of 24" (vs. 20") in school buses	$150,000
1124	Crossing control arms for school buses	$410,000
1124	Signal arms on school buses	$430,000
1124	External loud speakers on school buses	$590,000
1124	Mechanical sensors for school buses	$1,200,000
1124	Electronic sensors for school buses	$1,500,000
1124	Seat belts for passengers in school buses	$2,800,000
1124	Staff school buses with adult monitors	$4,900,000
Speed limit		
9	National (vs. state and local) 55 mph speed limit on highways and interstates	$6,600
175	Full (vs. 50%) enforcement of national 55 mph speed limit	$16,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
353	National (vs. state and local) 55 mph speed limit on highways and interstates	$30,000
185	National (vs. state and local) 55 mph speed limit on highways	$59,000
2	National (vs. state and local) 55 mph speed limit	$89,000
185	National (vs. state and local) 55 mph speed limit on rural interstates	$510,000
Traffic safety education		
175	Driver improvement schools (vs. suspending/revoking license) for bad drivers	≤ $0
175	Media campaign to increase voluntary use of seat belts	$310
175	Public pedestrian safety information campaign	$500
175	Improve traffic safety information for children grades K–12	$710
175	Motorcycle rider education program	$5,700
175	Improve motorcycle testing and licensing system	$8,700
157	Improve basic driver training	$20,000
175	Alcohol safety programs for drunk drivers	$21,000
175	Multimedia retraining courses for injury-prone drivers	$23,000
175	Improve educational curriculum for beginning drivers	$84,000
175	First aid training for drivers	$180,000
1124	Improve pedestrian education programs for school bus passengers grades K-6	$280,000
175	Warning letters sent to problem drivers	$720,000
Vehicle inspection		
864	Random motor vehicle inspection	$1,500
1172	Compulsory annual motor vehicle inspection	$20,000
864	Periodic motor vehicle inspection	$21,000
64	Periodic motor vehicle inspection	$57,000
175	Periodic inspection of motor vehicle sample focusing on critical components	$390,000
175	Periodic motor vehicle inspection	$1,300,000
Injury reduction interventions, miscellaneous		
192	Terminate sale of three-wheeled All-Terrain Vehicles	≤ $0
175	Require front and rear lights to be on when motorcycle is in motion	$1,100
175	Selective traffic enforcement programs at high-risk times and locations	$5,200
217	Insulate omnidirectional CB antennae to avert electrocution	$8,500
311	Oxygen depletion sensor systems for gas space heaters	$13,000
863	Require employers to ensure employees' motor vehicle safety	$25,000
372	"American" oxygen depletion sensor system for gas space heaters	$51,000
1160	Workplace practice standard for electric power generation operation	$59,000
175	Pedestrian and bicycle visibility enhancement programs	$73,000
315	Lock out or tag out of machinery in repair	$99,000
372	"French" oxygen depletion sensor system for gas space heaters	$130,000
1005	Redesign chain saws to reduce rotational kickback injuries	$230,000
101	Ground fault circuit interrupters	$1,100,000
468	Ejection system for the Air Force B-58 bomber	$1,200,000
1161	Equipment, work practices, and training standard for hazardous waste cleanup	$2,000,000
	Toxin control	
Arsenic control		
497	Arsenic emission standard (vs. capture and control) at high-emit copper smelters	$36,000
1216	Arsenic emission control at high-emitting copper smelters	$74,000
497	Arsenic emission standard (vs. capture and control) at glass plants	$2,300,000
1183	Arsenic emission control at low-emitting ASARCO/El Paso copper smelter	$2,600,000
1216	Arsenic emission control at glass plants	$2,900,000
497	Arsenic emission standard (vs. capture and control) at low-emit copper smelters	$3,900,000
881	Arsenic emission control at secondary lead plants	$7,600,000
1216	Arsenic emission control at low-emitting copper smelters	$16,000,000
1183	Arsenic emission control at low-emitting copper smelters	$29,000,000
881	Arsenic emission control at primary copper smelters	$30,000,000
881	Arsenic emission control at glass manufacturing plants	$51,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
1183	Arsenic emission control at low-emitting Copper Range/White Pine copper smelter	$890,000,000
	Asbestos control	
881	Ban asbestos in brake blocks	$29,000
819	Asbestos exposure standard of 1.0 (vs. 2.0) fibers/cc in asbestos cement industry	$55,000
881	Ban asbestos in pipeline wrap	$65,000
881	Ban asbestos in specialty paper	$80,000
651	Ban products containing asbestos (vs. 0.2 fibers/cc standard)	$220,000
651	Phase in ban of products containing asbestos (vs. 0.2 fibers/cc standard)	$240,000
819	Asbestos exposure standard of 1.0 (vs. 2.0) fibers/cc in textile industry	$400,000
387	Asbestos exposure standard of 0.2 (vs. 2.0) fibers/cc in ship repair industry	$410,000
881	Ban asbestos in roofing felt	$550,000
881	Ban asbestos in friction materials	$580,000
881	Ban asbestos in non-roofing coatings	$790,000
881	Ban asbestos in millboard	$920,000
819	Asbestos exposure standard of 0.2 (vs. 0.5) fibers/cc in friction products industry	$1,200,000
819	Asbestos exposure standard of 0.2 (vs. 0.5) fibers/cc in cement industry	$1,900,000
881	Ban asbestos in beater-add gaskets	$2,000,000
881	Ban asbestos in clutch facings	$2,700,000
881	Ban asbestos in roof coatings	$5,200,000
881	Ban asbestos in sheet gaskets	$5,700,000
881	Ban asbestos in packing	$5,700,000
819	Ban products containing asbestos (vs. 0.5 fibers/cc) in textile industry	$6,800,000
881	Ban asbestos in reinforced plastics	$8,200,000
881	Ban asbestos in high grade electrical paper	$15,000,000
387	Asbestos exposure standard of 0.2 (vs. 2.0) fibers/cc in construction industry	$29,000,000
881	Ban asbestos in thread, yarn, etc.	$34,000,000
819	Asbestos exposure standard of 1.0 (vs. 2.0) fibers/cc in friction products industry	$41,000,000
881	Ban asbestos in sealant tape	$49,000,000
881	Ban asbestos in automatic transmission components	$66,000,000
881	Ban asbestos in acetylene cylinders	$350,000,000
881	Ban asbestos in missile liner	$420,000,000
881	Ban asbestos in diaphragms	$1,400,0000,000
	Benzene control	
1139	Benzene exposure standard of 1 (vs. 10) ppm in rubber and tire industry	$76,000
881	Control of new benzene fugative emissions	$230,000
881	Control of existing benzene fugative emissions	$240,000
721	Benzene exposure standard of 1 (vs. 10) ppm	$240,000
881	Benzene emission control at pharmaceutical manufacturing plants	$460,000
881	Benzene emission control at coke by-product recovery plants	$1,400,000
1139	Benzene exposure standard of 1 (vs. 10) ppm in coke and coal chemicals industry	$3,000,000
881	Benzene emission control during transfer operations	$4,100,000
881	Control of benzene storage vessels	$14,000,000
881	Benzene emission control at ethylbenzene/styrene process vents	$14,000,000
881	Benzene emission control during waste operations	$19,000,000
881	Benzene emission control at maleic anhydride plants	$20,000,000
881	Benzene emission control at service stations storage vessels	$91,000,000
881	Control of benzene equipment leaks	$98,000,000
881	Benzene emission control at chemical manufacturing process vents	$180,000,000
881	Benzene emission control at bulk gasoline plants	$230,000,000
881	Benzene emission control at chemical manufacturing process vents	$530,000,000
881	Benzene emission control at rubber tire manufacturing plants	$20,000,000,000
	Chlorination	
42	Chlorination of drinking water	$3,100
42	Chlorination, filtration and sedimentation of drinking water	$4,200
	Coal and coke oven emissions control	
38	Coal-fired power plants emission control through high stacks etc.	≤ $0

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
38	Coal-fired power plants emission control through coal beneficiation etc.	$37,000
745	Coke oven emission standard for iron- or steel-producing plants	$130,000
745	Acrylonitrile emission control via best available technology	$9,000,000
	Formaldehyde control	
716	Ban urea-formaldehyde foam insulation in homes	$11,000
311	Ban urea-formaldehyde foam insulation in homes	$220,000
1164	Formaldehyde exposure standard of 1 (vs. 3) ppm in wood industry	$6,700,000
	Lead control	
1217	Reduced lead content of gasoline from 1.1 to 0.1 grams per leaded gallon	≤ $0
	1,3 Butadiene control	
1138	1,3 Butadiene exposure standard of 10 (vs. 1000) ppm PEL in polymer plants	$340,000
1138	1,3 Butadiene exposure standard of 2 (vs. 1000) ppm PEL in polymer plants	$770,000
	Pesticide control	
713	Ban chlorobenzilate pesticide on noncitrus	≤ $0
403	Ban amitraz pesticide on apples	≤ $0
403	Ban amitraz pesticide on pears	$350,000
713	Ban chlorobenzilate pesticide on citrus	$1,200,000
	Pollution control at paper mills	
844	Chloroform emission standard at 17 low cost pulp mills	≤ $0
844	Chloroform private well emission standard at 7 papergrade sulfite mills	$25,000
844	Chloroform private well emission standard at 7 pulp mills	$620,000
844	Chloroform reduction by replacing hypochlorite with chlorine dioxide at 1 mill	$990,000
844	Dioxin emission standard of 5 lbs/air dried ton at pulp mills	$4,500,000
844	Dioxin emission standard of 3 (vs. 5) lbs/air dried ton at pulp mills	$7,500,000
844	Chloroform emission standard of 0.001 (vs. 0.01) risk level at pulp mills	$7,700,000
844	Chloroform reduction by replace hypochlorite with chlorine dioxide at 70 mills	$8,700,000
844	Chloroform reduction at 70 (vs. 33 worst) pulp and paper mills	$15,000,000
844	Chloroform reduction at 33 worst pulp and paper mills	$57,000,000
844	Chloroform private well emission standard at 48 pulp mills	$99,000,000,000
	Radiation control	
468	Automatic collimators on X-ray equipment to reduce radiation exposure	$23,000
881	Radionuclide emission control at underground uranium mines	$79,000
881	Radionuclide emission control at Department of Energy facilities	$730,000
1216	Radionuclide control via best available technology in uranium mines	$850,000
44	Radiation standard "as low as reasonably achievable" for nuclear power plants	$1,100,000
468	Radiation levels of 0.3 (vs. 1.0) WL at uranium mines	$1,600,000
1215	Radiation standard "as low as reasonably achievable" for nuclear power plants	$2,500,000
881	Radionuclide emission control at surface uranium mines	$3,900,000
881	Radionuclide emission control at elemental phosphorous plants	$9,200,000
881	Radionuclide emission control at operating uranium mill tailings	$11,000,000
1216	Radionuclide control via best available technology in phosphorous mines	$16,000,000
881	Radionuclide emission control at phosphogypsum stacks	$29,000,000
881	Radionuclide emission control during disposal of uranium mill tailings piles	$40,000,000
1216	Rdiation emission standard for nuclear power plants	$100,000,000
468	Radiation emission standard for nuclear power plants	$180,000,000
926	Thin, flexible, protective leaded gloves for radiologists	$190,000,000
881	Radionuclide emission control at coal-fired industrial boilers	$260,000,000
881	Radionuclide emission control at coal-fired utility boilers	$2,400,000,000
881	Radionuclide emission control at NRC-licensed and non-DOE facilities	$2,600,000,000
881	Radionuclide emission control at uranium fuel cycle facilities	$34,000,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Radon control	
1266	Radon remediation in homes with levels ≥ 21.6 pCi/L	$6,100
1267	Radon remediation in homes with levels ≥ 8.11 pCi/L	$35,000
1030	Radon limit after disposal of uranium mill tailings of 20 (vs. 60) p(i/m2s)	$49,000
1265	Radon remediation in homes with levels ≥ 4 pCi/L	$140,000
1030	Radon limit after disposal of uranium mill tailings of 2 (vs. 6) p(i/m2s)	$260,000
881	Radon emission control at Department of Energy facilities	$5,100,000
	SO2 control	
923	SO2 controls by installation of capacity to desulphurize residual fuel oil	≤ $0
	Trichloroethylene control	
1215	Trichloroethylene standard of 2.7 (vs. 11) microgram/L in drinking water	$34,000,000
	Vinyl chloride control	
881	Vinyl chloride emission control at EDC/VC and PVC plants	$1,600,000
718	Vinyl chloride emission standard	$1,700,000
	VOC control	
1122	South Coast of California ozone control program	$610,000
	Toxin control, miscellaneous	
725	Process safety standard for management of hazardous chemicals	$77,000

Medicine

	Alpha antitrypsin replacement therapy	
1004	Alpha antitrypsin replacement (vs. med) therapy for smoking men age 70	$31,000
1004	Alpha antitrypsin replacement (vs. med) therapy for smoking women age 40	$36,000
1004	Alpha antitrypsin replacement (vs. med) therapy for nonsmoking women age 30	$56,000
1004	Alpha antitrypsin replacement (vs. med) therapy for nonsmoking men age 60	$80,000
	Beta-blocker treatment following myocardial infarction	
952	Beta blockers for myocardial infarction survivors with no angina or hypertension	$360
952	Beta-blockers for myocardial infarction survivors	$850
176	Beta-blockers for high-risk myocardial infarction survivors	$3,000
176	Beta-blockers for low-risk myocardial infarction survivors	$17,000
	Breast cancer screening	
142	Mammography for women age 50	$810
283	Mammography every 3 years for women age 50–65	$2,700
658	Annual mammography and breast exam for women age 35–49	$10,000
658	Annual physical breast cancer exam for womena age 35–49	$12,000
611	Annual mammography and breast exam (vs. just exam) for women age 40–64	$17,000
1230	Annual mammography and breast exam for women age 40–49	$62,000
1230	Annual mammography and breast exam (vs. just exam) for women age 40–49	$95,000
86	Annual mammography for women age 55–64	$110,000
1230	Annual mammography (vs. current screening practices) for women age 40–49	$190,000
	Breast cancer treatment	
1238	Postsurgical chemotherapy for premenopausal women with breast cancer	$18,000
1238	Postsurgical chemotherapy for women with breast cancer age 60	$22,000
1269	Bone marrow transplant and high (vs. standard) chemotherapy for breast cancer	$130,000
	Cervical cancer screening	
1316	Cervical cancer screening every 3 years for women age 65+	≤ $0
120	Cervical cancer screening every 9 (vs. 10) years for women age 30–39	$410
618	One time mass screening for cervical cancer for women age 38	$1,200
1316	Cervical cancer screening every 5 years for women age 65+	$1,900
1316	One time cervical cancer screening for women age 65+	$2,100

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
120	Cervical cancer screening every 2 (vs. 3) years for women age 30–39	$2,300
1316	Cervical cancer screening every 3 years for women age 65+	$2,800
120	Annual (vs. every 2 years) cervical cancer screening for women age 30–39	$4,100
783	One time cervical cancer screening for never-screened poor women age 65	$5,000
707	Annual cervical cancer screening for women beginning at age 60	$11,000
81	Cervical cancer screening every 4 years (vs. never) for women age 20	$12,000
88	One time mass screening for cervical cancer	$13,000
258	Cervical cancer screening every 5 years for women age 35+ with 3+ kids	$32,000
1316	Cervical cancer screening every 3 years for regularly-screened women age 65+	$41,000
1316	Annual (vs. every 3 years) cervical cancer screening for women age 65+	$49,000
707	Annual cervical cancer screening for women beginning at age 21	$50,000
603	Annual cervical cancer screening for women beginning at age 20	$82,000
81	Cervical cancer screening every 3 (vs. 4) years for women age 20	$220,000
456	Annual cervical cancer screening for women beginning at age 20	$220,000
81	Cervical cancer screening every 2 (vs. 3) years for women age 20	$310,000
81	Annual (vs. every 2 years) cervical cancer screening for women age 20	$1,500,000
Childhood immunization		
65	Immunization for all infants and pre-school children (vs. scattered efforts)	≤ $0
143	Pertussis, diphtheria, and tetanus (vs. just diphtheria and tetanus) immunization	≤ $0
349	Measles, mumps, and rubella immunization for children	≤ $0
812	Polio immunization for children age 0–4	≤ $0
812	Rubella vaccination for children age 2	≤ $0
1178	National measles eradication program for children	≤ $0
Cholesterol screening		
605	Cholesterol screening for boys age 10 and their first-degree relatives	$4,600
605	Cholesterol screening for boys age 10	$6,500
Cholesterol treatment		
1071	Lovastatin for men age 35–54 with heart disease and ≥ 250 mg/dL	≤ $0
785	Low-cholesterol diet for men age 60 and 180 mg/dL	$12,000
2	Low-cholesterol diet for men age 30	$19,000
1071	Lovastatin for men age 55–64 with heart disease and < 250 mg/dL	$20,000
791	Oat bran cholesterol reduction for men age 48 and > 265 mg/dL	$24,000
785	Lovastatin/low cholesterol diet (vs. diet) for men age 60 and 300 mg/dL	$26,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 60 and 300 mg/dL	$31,000
1071	Lovastatin for men age 45–54 with no heart disease and ≥ 300 mg/dL	$34,000
768	Cholestyramine/low cholesterol diet (vs. diet) for age 35–39 and 290 mg/dL	$100,000
768	Cholestyramine/low cholesterol diet (vs. diet) for men age 50–54 and 290 mg/dL	$150,000
791	Cholestyramine for men age 48 and > 265 mg/dL	$160,000
768	Cholestyramine/low cholesterol diet (vs. cholestyramine) age 35–39 290 mg/dL	$200,000
1191	Cholestyramine for men with cholesterol levels above the 95th percentile	$230,000
785	Low-cholesterol diet for men age 20 and 180 mg/dL	$360,000
1071	Lovastatin 40 (vs. 20) mg for women age 35–44 with heart disease < 250 mg/dL	$360,000
768	Cholestyramine/low cholesterol diet (vs. diet) for men age 65–69 and 290 mg/dL	$920,000
1071	Lovastatin for women age 35–44 with no heart disease and ≥ 300 mg/dL	$1,200,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 20 and 240 mg/dL	$1,300,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 20 and 240 mg/dL	$1,800,000
Clinical trials		
1134	Women's Health Trial to evaluate low-fat diet in reducing breast cancer	$18,000
1004	Clinical trial to evaluate alpha antitrypsin replacement therapy	$53,000
Colorectal screening		
86	Annual stool guaiac colon cancer screening for people age 55+	≤ $0
96	One stool guaiac colon cancer screening for people age 40+	$660
528	One hemoccult screening for colorectal cancer for asymptomatic people age 55	$1,300
1135	Colorectal cancer screening for people age 40+	$4,500
1135	Colonoscopy for colorectal cancer screening for people age 40+	$90,000
96	Six (vs. five) stool guaiacs colon cancer screening for people age 40+	$26,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Coronary artery bypass graft surgery (CABG)	
358	Left main coronary artery bypass graft surgery (vs. medical management)	$2,300
99	Left main coronary artery bypass graft surgery (vs. medical management)	$5,600
99	3-vessel coronary artery bypass graft surgery (vs. medical management)	$12,000
1200	3-vessel coronary artery bypass graft surgery (vs. PTCA) for severe angina	$23,000
358	2-vessel coronary artery bypass graft surgery (vs. medical management)	$28,000
99	2-vessel coronary artery bypass graft surgery (vs. medical management)	$75,000
1200	3-vessel coronary artery bypass graft surgery (vs. PTCA) for mild angina	$100,000
1200	2-vessel coronary artery bypass graft surgery (vs. PTCA) for severe angina	$430,000
	Drug and alcohol treatment	
86	Occupational assistance programs for working problem-drinkers	≤ $0
650	Detoxification for heroin addicts	≤ $0
650	Methadone maintenance for heroin addicts	≤ $0
650	Narcotic antagonists for heroin addicts	≤ $0
	Emergency vehicle response	
987	Defibrillators in emergency vehicles for resuscitation after cardiac arrest	$39
987	Defibrillators in emergency vehicles staffed with paramedics (vs. EMTs)	$390
986	Defibrillators in ambulances for resuscitation after cardiac arrest	$460
987	Emergency vehicle response for cardiac arrest	$820
2	Advanced life support paramedical equipped vehicle	$5,400
237	Advanced resuscitative care (vs. basic emergency services) for cardiac arrest	$27,000
175	Combined emergency medical services for coordinated rapid response	$120,000
	Gastrointestinal screening and treatment	
578	Sclerotherapy (vs. medical therapy) for esophageal bleeding in alcoholics	≤ $0
148	Truss (vs. elective inguinal herniorrhaphy) for inguinal hernia in elderly patients	≤ $0
352	Expectant management of silent gallstones in men age 30	≤ $0
797	Home (vs. hospital) parenteral nutrition for patients with acute loss of bowels	≤ $0
797	Home parenteral nutrition for patients with acute loss of bowels	≤ $0
584	Pre-operative total parenteral nutrition in gastrointestinal cancer patients	≤ $0
235	Ulcer therapy (vs. surgery) for duodenal ulcers	$6,600
577	Medical or surgical treatment for advanced esophageal cancer	$12,000
587	Surgery for liver cirrhosis patients with acute variceal bleeding	$17,000
1046	Ulcer (vs. symptomatic) therapy for episodic upper abdomen discomfort	$41,000
1067	Misoprostol to prevent drug-induced gastrointestinal bleed in at-risk patients	$47,000
587	Medical management for liver cirrhosis patients with acute variceal bleeding	$61,000
1067	Misoprostol to prevent drug-induced gastrointestinal bleed	$210,000
1046	Upper gastrointestinal X-ray and endoscopy (vs. ulcer therapy) for gastric cancer	$300,000
1046	Upper gastrointetinal X-ray and endoscopy (vs. antacids) for gastric cancer	$420,000
	Heart disease screening and treatment, miscellaneous	
518	Exercise stress test for asymptomatic men age 60	$40
358	Pacemaker implant (vs. medical management) for atrioventricular heart block	$1,600
251	Reconstruct mitral valve for symptomatic mitral valve disease	$6,700
350	Exercise stress test for age 60 with mild pain and no left ventricular dysfunction	$13,000
990	Implantable cardioverter-defibrillator (vs. medical therapy) for cardiac arrest	$23,000
1066	Coronary angiogaphy (vs. medical therapy) in men age 45–64 with angina	$28,000
346	Regular leisure time physical activity, such as jogging, in men age 35	$38,000
251	Replace (vs. reconstruct) mitral valve for symptomatic mitral valve disease	$150,000
	Heart transplantation	
544	Heart transplantation for patients age 55 or younger and favorable prognosis	$3,600
835	Heart transplantation for patients age 50 with terminal heart disease	$100,000
	HIV/AIDS screening and prevention	
6	Voluntary (vs. limited) screening for HIV in female drug users and sex partners	≤ $0
1097	Screen blood donors for HIV	$14,000
1100	Screen donated blood for HIV with an additional FDA-licensed test	$880,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
1102	Universal (vs. category-specific) precautions to prevent HIV transmission	$890,000
	HIV/AIDS treatment	
1199	Zidovudine for asymptomatic HIV+ people	≤ $0
1121	Oral dapsone for prophylaxis of PCP in HIV+ people	$16,000
1121	Aerosolized pentamidine for prophylaxis of PCP in HIV+ people	$20,000
1096	AZT for people with AIDS	$26,000
1264	Prophylactic AZT following needlestick injury in health care workers	$41,000
1117	Zidovudine for asymptomatic HIV+ people	$45,000
	Hormone replacement therapy	
227	Estrogen for menopausal women age 50	≤ $0
748	Estrogen-progestin for symptomatic monopausal women age 50	$15,000
748	Estrogen for symptomatic menopausal women age 50	$26,000
748	Estrogen-progestin for 15 years in asymptomatic menopausal women age 50	$30,000
748	Estrogen-progestin for 5 years in asymptomatic menopausal women age 50	$32,000
90	Estrogen for post-menopausal women age 55–70	$36,000
227	Estrogen for menopausal women age 50	$42,000
90	Estrogen for asymptomatic post-menopausal women age 50–65	$77,000
90	Estrogen for symptomatic post-menopausal women age 50–65	$81,000
748	Estrogen for asymptomatic menopausal women age 50	$89,000
244	Hormone replacement for asymptomatic perimenopausal white women age 50	$120,000
227	Estrogen-progestin for post-menopausal women age 60	$130,000
90	Estrogen for asymptomatic post-menopausal women age 55–70	$250,000
	Hypertension drugs	
225	Antihypertensive drugs for men age 25+ and 125 mmHg	$3,800
225	Antihypertensive drugs for men age 25+ and 85 mmHg	$4,700
1068	Beta-blockers for hypertensive patients age 35–64 no heart disease and ≥ 95 mmHg	$14,000
91	Antihypertensive drugs for patients age 40 and ≥ 105 mmHg	$16,000
91	Antihypertensive drugs for patients age 40 and 95–104 mmHg	$32,000
1068	Captopril for people age 35–64 with no heart disease and ≥ 95 mmHg	$93,000
	Hypertension screening	
111	Hypertension screening for Black men age 55–64 and ≥ 90 mmHg	$5,000
761	Hypertension screening for men age 45–54	$5,200
111	Hypertension screening for White men age 45–54 and ≥ 90 mmHg	$6,500
111	Hypertension screening for Black women age 45–54 and ≥ 90 mmHg	$8,400
1202	Hypertension screening for asymptomatic men age 60	$11,000
1202	Hypertension screening for asymptomatic women age 60	$17,000
1202	Hypertension screening for asymptomatic men age 40	$23,000
761	Hypertension screening every 5 years for men age 55–64	$31,000
1202	Hypertension screening for asymptomatic women age 40	$36,000
111	Hypertension screening for White women age 18–24 and ≥ 90 mmHg	$37,000
1202	Hypertension screening for asymptomatic men age 20	$48,000
1202	Hypertension screening for asymptomatic women age 20	$87,000
	Hysterectomy to prevent uterine cancer	
750	Hysterectomy without oopherectomy for asymptomatic women age 35	≤ $0
750	Hysterectomy with oopherectomy for asymptomatic women age 40	$51,000
758	Hysterectomy for asymptomatic women age 35	$230,000
	Influenza vaccination	
455	Influenza vaccination for all citizens	$140
156	Influenza vaccination for high risk people	$570
156	Influenza vaccination for people age 5+	$1,300
	Intensive care	
422	Coronary care unit for patients under age 65 with cardiac arrest	$390
125	Intensive care for young patients with barbiturate overdose	$490
1208	Intensive care and mechanical ventilation for acute respiratory distress syndrome	$3,100

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
125	Intensive care for young patients with polyradiculitis	$3,600
1208	Intensive care and mechanical ventilation for acute respiratory failure	$4,700
854	Intensive care for unstable patients with unpredictable clinical course	$21,000
1208	Intensive care for patients with heart disease and respiratory failure	$21,000
125	Intensive care for patients with multiple trauma	$26,000
89	Coronary care unit for emergency patients with acute chest pain	$250,000
602	Intensive care for very ill patients undergoing major vascular surgery	$300,000
602	Intensive care for very ill patients with operative complications	$390,000
602	Intensive care for seriously ill patients with multiple trauma	$460,000
602	Intensive care for very ill patients undergoing neurosurgery for head trauma	$490,000
125	Intensive care for men with advanced cirrhosis, kidney and liver failure	$530,000
602	Intensive care for very ill patients with emergency abdominal catastrophes	$660,000
602	Intensive care for very ill patients undergoing neoplastic disease operations	$820,000
602	Intensive care for very ill patients undergoing major vascular operations	$850,000
602	Intensive care for very ill patients with gastrointestinal bleeding, cirhosis etc.	$950,000
	Leukemia treatment and infection control	
1095	Bone marrow transplant (vs. chemotherapy) for acute nonlymphocytic leukemia	$12,000
1095	Bone marrow transplant for acute nonlymphocytic leukemia in adults	$20,000
1095	Chemotherapy for acute nonlymphocytic leukemia in adults	$27,000
672	Therapeutic leukocyte transfusion to prevent infection during chemotherapy	$36,000
672	Prophylactic (vs. therapeutic) leukocyte transfusion to prevent infection	$210,000
1239	Intravenous immune globulin to prevent infections in leukemia patients	$7,100,000
	Neonatal intensive care	
335	Neonatal intensive care for infants weighing 1000–1499 grams	$5,700
83	Neonatal intensive care for infants weighing 751–1000 grams	$5,800
335	Neonatal intensive care for infants weighing 500–999 grams	$18,000
1249	Neonatal intensive care for low birth weight infants	$270,000
	Newborn screening	
1195	PKU genetic disorder screening in newborns	≤ $0
1196	Congenital hypothyroidism screening in newborns	≤ $0
1141	Sickle cell screening for Black newborns	$240
1141	Sickle cell screening for non-Black high risk newborns	$110,000
1141	Sickle cell screening for newborns	$65,000,000
1141	Sickle cell screening for non-Black low risk newborns	$34,000,000,000
	Organized health services	
1249	Special supplemental food program for women, infants, and children	$3,400
653	Comprehensive (vs. fragmented) health care services	$5,700
653	Comprehensive (vs. fragmented) health care services for mothers and children	$11,000
1249	Organized family planning services for teenagers	$16,000
1191	No cost-sharing (vs. cost sharing) for health care services	$74,000
1249	Community health care services for women and infants	$100,000
	Osteoporosis screening	
244	Bone mass screening and treat if < 0.9 g/(cm)^2 for perimenopausal women age 50	$13,000
244	Bone mass screening and treat if < 1.0 g/(cm)^2 for perimenopausal women age 50	$18,000
244	Bone mass screening and treat if < 1.1 g/(cm)^2 for perimenopausal women age 50	$41,000
	Percutaneous transluminal coronary angioplasty (PTCA)	
358	PTCA (vs. medical management) for men age 55 with severe angina	$5,300
1200	PTCA (vs. medical management) for men age 55 with severe angina	$7,400
358	PTCA (vs. medical management) for men age 55 with mild angina	$24,000
1200	PTCA (vs. medical management) for men age 55 with mild angina	$110,000
	Pneumonia vaccination	
812	Pneumonia vaccination for people age 65+	$1,800
782	Pneumonia vaccination for people age 65+	$2,000
347	Pneumonia vaccination for people age 65+	$2,200

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
693	Pneumonia vaccination for people age 65+	$2,200
812	Pneumonia vaccination for high risk immunodeficient people age 65+	$6,500
812	Pneumonia vaccination for people age 45–64	$10,000
782	Pneumonia vaccination for high risk people age 25–44	$14,000
812	Pneumonia vaccination for high risk immunodeficient people age 45–64	$28,000
782	Pneumonia vaccination for low risk people age 25–44	$66,000
782	Pneumonia vaccination for children age 2–4	$160,000
347	Pneumonia vaccination for children age 2–4	$170,000
693	Pneumonia vaccination for children age 2–4	$170,000
Prenatal care		
1253	Term guard uterine activity monitor (vs. self-palpation) to detect contractions	≤ $0
924	Financial incentive of $100 to seek prenatal care for low risk women	≤ $0
1250	Universal (vs. existing) prenatal care for women with < 12 years of education	≤ $0
1250	Universal (vs. existing) prenatal care for women with > 12 years of education	≤ $0
1250	Universal (vs. existing) prenatal care for women with 12 years of education	≤ $0
1251	Prenatal screening for hepatitis B in high risk women	≤ $0
1220	Brady method screening for group B streptococci colonization during labor	≤ $0
1256	Prenatal care for pregnant women	≤ $0
340	Antepartum Anti-D treatment for Rh-negative primiparae pregnancies	$1,100
1249	Prenatal care for pregnant women	$2,100
340	Antepartum Anti-D treatment for Rh-negative multiparae pregnancies	$2,900
1220	Isada method screening for group B streptococci colonization during labor	$5,000
Renal dialysis		
801	Home dialysis for chronic end-stage renal disease	$20,000
1049	Home dialysis for end-stage renal disease	$22,000
157	Home dialysis for end-stage renal disease	$23,000
139	Home dialysis for people age 45 with chronic renal disease	$24,000
419	Home dialysis for people age 64 or younger with chronic renal disease	$25,000
1049	Hospital dialysis for end-stage renal disease	$31,000
418	Home dialysis for people age 55–60 with acute renal failure	$32,000
357	Dialysis for people age 35 with end-stage renal disease	$38,000
419	Hospital dialysis for people age 55–64 with chronic renal failure	$42,000
689	Home dialysis for end-stage renal disease	$46,000
418	Hospital dialysis for people age 55–60 with acute renal failure	$47,000
342	Dialysis for end-stage renal disease	$51,000
1049	Center dialysis for end-stage renal disease	$55,000
1050	Center dialysis for end-stage renal disease	$63,000
157	Center dialysis for end-stage renal disease	$64,000
139	Center dialysis for people age 45 with chronic renal disease	$67,000
801	Center dialysis for end-stage renal disease	$68,000
689	Center dialysis for end-stage renal disease	$71,000
342	Hospital dialysis for end-stage renal disease	$74,000
689	Home dialysis (vs. transplantation) for end-stage renal disease	$79,000
Renal dialysis and transplantation		
689	Home dialysis then transplant for end-stage renal disease	$40,000
689	Hospital dialysis then transplant for end-stage renal disease	$46,000
Renal transplantation and infection control		
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$3,500
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$14,000
157	Kidney transplant for end-stage renal disease	$17,000
419	Kidney transplant and dialysis for people age 15–34 with chronic renal failure	$17,000
139	Kidney transplant for people age 45 with chronic renal disease	$19,000
1050	Kidney transplant from live-related donor for end-stage renal disease	$19,000
357	Kidney transplant from cadaver with cyclosporine (vs. azathioprine)	$27,000
357	Kidney transplant from cadaver with cyclosporine	$29,000
357	Kidney transplant from cadaver with azathioprine	$29,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$200,000
Smoking cessation advice		
1185	Smoking cessation advice for pregnant women who smoke	≤ $0
952	Smoking cessation among patients hospitalized with myocardial infarction	≤ $0
773	Smoking cessation advice for men age 50–54	$990
773	Smoking cessation advice for men age 45–49	$1,100
773	Smoking cessation advice for men age 35–39	$1,400
773	Smoking cessation advice for women age 50–54	$1,700
773	Smoking cessation advice for women age 45–49	$1,900
773	Smoking cessation advice for women age 35–39	$2,900
771	Nicotine gum (vs. no gum) and smoking cessation advice for men age 45–49	$5,800
119	Nicotine gum (vs. no gum) and smoking cessation advice for men age 35–69	$7,500
771	Nicotine gum (vs. no gum) and smoking cessation advice for men age 65–69	$9,100
771	Nicotine gum (vs. no gum) and smoking cessation advice for women age 50–54	$9,700
86	Smoking cessation advice for people who smoke more than one pack per day	$9,800
119	Nicotine gum (vs. no gum) and smoking cessation advice for women age 35–69	$11,000
771	Nicotine gum (vs. no gum) and smoking cessation advice for women age 65–69	$13,000
Tuberculosis treatment		
784	Isoniazid chemotherapy for high risk White male tuberculin reactors age 20	≤ $0
784	Isoniazid chemotherapy for low risk White male tuberculin reactors age 55	$17,000
Venous thromboembolism prevention		
230	Heparin (vs. anticoagulants) to prevent venous thromboembolism	≤ $0
769	Compression stockings to prevent venous thromboembolism	≤ $0
770	Compression stockings to prevent venous thromboembolism	≤ $0
770	Heparin to prevent venous thromboembolism	≤ $0
770	Heparin and dihydroergotamine to prevent venous thromboembolism	≤ $0
770	Intermittent pneumatic compression to prevent venous thromboembolism	≤ $0
770	Heparin and stockings to prevent venous thromboembolism	≤ $0
770	Warfarin sodium to prevent venous thromboembolism	≤ $0
769	Intermittent pneumatic compression and stockings to prevent thromboembolism	$400
230	Dextran (vs. anticoagulants) to prevent venous thromboembolism	$640
769	Heparin to prevent venous thromboembolism	$960
769	Heparin and stockings to prevent venous thromboembolism	$1,000
769	Heparin and dihydroergotamine to prevent venous thromboembolism	$1,700
769	Intermittent pneumatic compression to prevent venous thromboembolism	$2,400
787	Heparin, 1 day, for women with prosthetic heart valves undergoing surgery	$5,100
769	Heparin/dihydroergotamine (vs. stockings) to prevent venous thromboembolism	$42,000
787	Heparin, 3 days, for women with prosthetic heart valves undergoing surgery	$4,300,000
Medicine miscellaneous		
443	Broad-spectrum chemotherapy for cancer of unknown primary origin	≤ $0
728	Cefoxitin/gentamicin (vs. ceftizoxime) for intra-abdominal infection	$880
728	Mezlocillin/gentamicin (vs. ceftizoxime) for hospital acquired pneumonia	$1,400
646	Computed tomography in patients with severe headache	$4,800
709	Continuous (vs. nocturnal) oxygen for hypoxemic obstructive lung disease	$7,000
906	Preoperative chest X-ray to detect abnormalities in children	$360,000

[a] Reference numbers correspond to records in the database and to the references listed in Appendix B.

[b] Due to space limitations, life-saving interventions are described only briefly. When the original author compared the intervention to a baseline of "the status quo" or "do nothing" the baseline intervention is omitted here. Other baseline interventions appear as "(vs.)." Cost-effectiveness estimates are based on the particular life-saving intervention, base case intervention, target population, data, and methods as detailed by the original author(s). It is suggested the reader review the original document to gain a full appreciation of the origination of the estimates.

[c] All costs are in 1993 U.S. dollars and were updated with the general consumer price index. To emphasize the approximate nature of estimates, they are rounded to two significant figures.

APPENDIX B. REFERENCES FOR COST-EFFECTIVENESS ANALYSES[a]

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[a] Reference numbers correspond to records in the database and to interventions described in Appendix A. Missing numbers reflect documents that were retrieved but did not contain suitable cost-effectiveness data.

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How attractive does a new technology have to be to warrant adoption and utilization? Tentative guidelines for using clinical and economic evaluations

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Because economic evaluations of health care services are being published with increasing frequency it is important to (a) evaluate them rigorously and (b) compare the net benefit of the application of one technology with that of others. Four "levels of evidence" that rate economic evaluations on the basis of their methodologic rigour are proposed. They are based on the quality of the methods used to estimate clinical effectiveness, quality of life and costs. With the use of the magnitude of the incremental net benefit of a technology, therapies can also be classified into five "grades of recommendation." A grade A technology is both more effective and cheaper than the existing one, whereas a grade E technology is less or equally effective and more costly. Those of grades B through D are more effective and more costly. A grade B technology costs less than $20 000 per quality-adjusted life-year (QALY), a grade C one $20 000 to $100 000/QALY and a grade D one more than $100 000/QALY. Many issues other than cost effectiveness, such as ethical and political considerations, affect the implementation of a new technology. However, it is hoped that these guidelines will provide a framework with which to interpret economic evaluations and to identify additional information that will be useful in making sound decisions on the adoption and utilization of health care services.

Puisqu'on publie de plus en plus souvent des évaluations économiques des services de soins de santé, il est important (a) d'évaluer rigoureusement ces derniers et (b) de comparer l'avantage net de l'utilisation d'une technologie par rapport à d'autres. Quatre «niveaux factuels» sont proposés pour coter les évaluations économiques d'après leur rigueur méthodologique. Ces niveaux reposent sur la qualité des modèles utilisés pour évaluer l'efficacité clinique, la qualité de la vie et les coûts. En tenant compte de l'ampleur des avantages cumulatifs nets d'une technologie, on peut également classer les thérapies en cinq «cotes de recommandation». Une technologie de cote A est à la fois efficace et moins coûteuse que la technologie en place, tandis qu'une technologie de cote E est tout au plus aussi efficace, mais plus coûteuse. Les technologies de cotes B à D sont plus efficaces et plus coûteuses. Une technologie de cote B coûte moins de 20 000 $ par année de vie pondérée par la qualité (AVPQ), une technologie de cote C, 20 000 $ à

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100 000 $ par AVPQ et une cote D, plus de 100 000 $ par AVPQ. En plus de la rentabilité, nombre de questions, par exemple les aspects déontologiques et politiques, influent sur la mise en application d'une nouvelle technologie. Cependant, on espère que les présentes lignes directrices offriront un cadre pour l'interprétation des évaluations économiques et l'identification de l'information supplémentaire qui sera utile pour prendre de bonnes décisions dans l'adoption et l'utilisation des services de soins de santé.

The number of published studies that include economic evaluations of health care services has increased in recent years, spurred by the large number of new therapeutic and diagnostic technologies, their associated costs and the limited resources available to pay for them. For the results of clinical and economic evaluations to be used for policy formulation it is important to develop an idea of the orders of magnitude of cost-effectiveness that are likely to be associated with wise adoption and utilization and with unwise use of health care resources.

How clinically and economically attractive does a technology have to be to warrant adoption and utilization? Although there is no definitive answer to the question, we propose a classification system in this article that provides guidance on the use of clinical and economic evaluations in making decisions about the adoption and utilization of competing health care technologies. Examples are provided of how published studies would be categorized, and the potential uses and limits of the system are discussed.

With the proposed system it will be possible to summarize the results of clinical and economic evaluations of health care technologies in terms of both the methodologic quality of the evaluations (levels of evidence) and the likely magnitude of net benefit from their application (grades of recommendation). The proposed classification scheme is modelled after the work of the Canadian Task Force on the Periodic Health Examination[1] and the National Institutes of Health–American College of Chest Physicians Task Force on the Use of Anti-thrombotic Agents.[2]

Levels of evidence

A complete economic evaluation considers both the effectiveness and the costs and includes the following six items (as adapted from reference 3).

1. All relevant clinical outcomes and costs are included in the analysis and valued sensibly. It is important to consider the methods used to establish effectiveness, estimate quality of life and measure costs. Criteria with which to assess the quality of these methods are provided in Appendix 1.
2. The analysis is incremental in that it compares the differences in costs and clinical outcomes of one specific technology (or policy) with those of another.
3. Costs and clinical outcomes are discounted.
4. Sensitivity analyses are used to assess the robustness of the conclusions.
5. The perspective of the decision-maker is clearly identified. This is usually the societal perspective, although it may be appropriate to take a purely organizational perspective (e.g., the hospital's) if the economic attractiveness of various options is being ranked within that organization.
6. The incremental cost–utility ratio identified must be compared with others in order to determine the economic attractiveness of one program over that of another.

A full economic study includes all six items. The level of evidence provided by such a study depends on the methodologic quality of the assessment of effectiveness, quality of life and costs (Appendix 1). A level I study uses the highest-quality assessment method for each of these three components, a level II study uses the highest-quality method for two, and a level III study uses the highest-quality method for one. All other studies are classified as level IV.

An example of a level I study is the economic comparison of a community-based treatment program for chronically disabled psychiatric patients and in-hospital management[4,5] (this was actually a cost–benefit analysis, so improvements in outcome were translated into dollar values rather than expressed as quality-adjusted life-years [QALYs]). Patients were randomly allocated to either type of care, resource use was collected prospectively, and costs were appropriately valued.

An example of a level II study is the economic evaluation of neonatal intensive care units by Boyle and associates.[6] Although the estimation of costs and quality of life was of high quality, effectiveness was assessed with a before–after study design.

It is recognized in some instances that the effectiveness of an intervention is so dramatic that a randomized controlled trial is not possible (e.g., heart transplantation v. no transplantation in patients with end-stage heart failure). In other instances the logistics of performing a randomized controlled trial are virtually insurmountable because the outcome of interest is so rare (e.g., evaluating universal precautions to prevent the spread of human immunodeficiency virus [HIV] infection).

Nevertheless, it is hoped that classifying studies into levels I through IV will allow the reader to be aware of the quality of the evidence.

Grades of recommendation

The decision about whether to implement a new therapy depends not only on the levels of evidence (the quality of the study) but also on the likely magnitude of the incremental costs required to achieve each additional unit of benefit. The suggested grades of recommendation (Table 1) classify therapies on the basis of the magnitude of their incremental net benefits.

A grade A technology is both more effective and less costly than the existing technology. There are, therefore, compelling reasons to introduce it or use it appropriately. Although most health care technologies do not meet the criteria for a grade A recommendation screening for phenylketonuria[7] and postpartum anti-D therapy[8] are examples that do.

Grade B through D technologies are classified as those that are (a) more effective and more costly than the existing technology or (b) less effective and less costly. Whether technologies are classified as grade B, C or D depends on the magnitude of the change in costs relative to outcome associated with their introduction (less than $20 000/QALY, $20 000 to $100 000/QALY or more than $100 000/QALY).

In this classification changes are measured relative to the costs and effects of the current policy, and a technology is classified as (a) or (b) depending on whether it has already been introduced into the health care system. For example, it has been estimated that the introduction of universal precautions to prevent HIV transmission to health care workers costs about $565 000 per additional life-year saved.[9] If universal precautions had not yet been introduced they would have been classified as grade Da (weak evidence for adoption or appropriate utilization). However, if a health care jurisdiction has already introduced universal precautions their abandonment is classified as grade Bb (in this case the "new" technology is standard precautions, and its abandonment would save more than $100 000/QALY). This is illustrated in Fig. 1.

In general, it seems harder to withdraw an expensive and relatively ineffective technology than to introduce an equally expensive and more effective one. However, some health care technologies have been adopted on the basis of weak clinical evidence

Table 1: Grades of recommendation for the adoption and appropriate utilization of new technologies

A. Compelling evidence for adoption and appropriate utilization
The new technology is as effective as or more effective than the existing one and is less costly.

B. Strong evidence for adoption and appropriate utilization
- a) The new technology is more effective than the existing one and costs less than $20 000 per quality-adjusted life-year (QALY) gained.
- b) The new technology is less effective than the existing one, but its introduction would save more than $100 000/QALY gained.

C. Moderate evidence for adoption and appropriate utilization
- a) The new technology is more effective than the existing one and costs $20 000 to $100 000/QALY gained.
- b) The new technology is less effective than the existing one, but its introduction would save $20 000 to $100 000/QALY gained.

D. Weak evidence for adoption and appropriate utilization
- a) The new technology is more effective than the existing one and costs more than $100 000/QALY gained.
- b) The new technology is less effective than the existing one, but its introduction would save less than $20 000/QALY gained.

E. Compelling evidence for rejection
The new technology is less effective than or as effective as the existing one and is more costly.

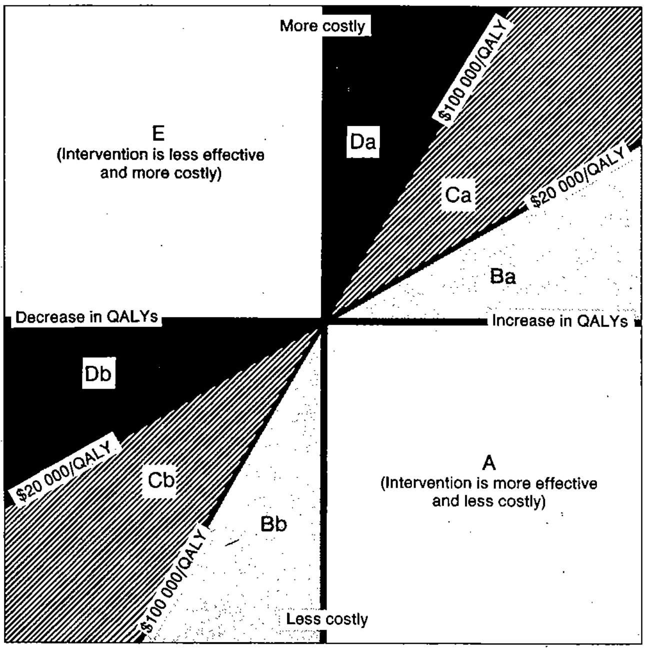

Fig. 1: Grades of recommendation: Grade A technologies should clearly be introduced or continued, and grade E technologies should not be introduced or should be abandoned. Technologies in the upper right quadrant are more effective and more costly than their alternatives, whereas those in the lower left quadrant are less effective and less costly. Introduction of technologies in the upper right quadrant and abandonment of the technologies with the same shading in the lower left quadrant lead to similar degrees of cost-effectiveness.

of effectiveness and without any formal economic evaluation. Thus, if resources can be saved (and put to better use elsewhere) policies that are relatively cost ineffective should be abandoned. On the other hand, one could argue that because standard practice has been in place for some time one should require a strong argument to justify a change.

For the sake of clarity the examples we will give of grades B through D technologies will be confined to those that are both more effective and more costly. Grade Ba technologies include coronary artery bypass grafting for left main coronary artery disease,[10] neonatal intensive care for infants weighing 1000 to 1499 g[6] and treatment in men with a diastolic blood pressure of 105 mm Hg or more.[11] An example of a grade Ca technology is hospital hemodialysis,[12] and examples of Grade Da technologies are the treatment of asymptomatic hyperlipidemia with cholestyramine,[13] the use of nonionic contrast media in patients at low risk of side effects[14] and the management of patients with low-risk myocardial infarction in a coronary care unit instead of intermediate care.[15]

Grade E technologies are more costly than existing technologies and less (or equally) effective. Before one can conclude that two technologies are equally effective the studies evaluating them must have sufficient power to detect small but clinically important differences. Examples of grade E technologies are extracranial–intracranial bypass grafting versus medical therapy for transient ischemic attacks[16] and the use of tissue plasminogen activator (tPA) versus streptokinase to treat acute myocardial infarction.[17]

The suggested cost cutoff points are in 1990 Canadian dollars. The nominal figures should be adjusted periodically to maintain constant value in real terms (adjusted for increases in the price level).

The time horizon chosen for an economic evaluation is important and can dramatically affect the grade of recommendation associated with the intervention. An example is bone marrow transplantation in acute nonlymphocytic leukemia. If a time horizon of 5 years were chosen the cost of transplantation compared with chemotherapy would be about $59 000 per additional year of life saved.[18] However, if the time horizon were extended over the life of the patient, then the cost would be about $10 000 per additional year of life saved.

Combining levels of evidence and grades of recommendation

The levels and grades can be combined to provide a summary of both the methodologic quality of the evidence and the magnitude of the net benefit associated with the therapy. For example, neonatal intensive care for infants weighing 1000 to 1499 g[6] is a Ba-II technology.

In some instances the evidence of either effectiveness or costs provided by methodologically suboptimal studies (e.g., those of levels II through IV) may be sufficient to justify its use in decision-making. Imagine an extremely expensive technology for which the clinical evidence is weak (e.g., no evidence from randomized controlled trials). One can take the most extreme assumption in favour of the intervention, and if the technology is economically unattractive under these conditions, then one is quite certain that it will still be unattractive even if a higher-quality method of assessing its effectiveness is used.

Such a situation arose recently with the introduction of tPA for the treatment of acute myocardial infarction. Despite the lack of a randomized controlled study comparing the rates of death among patients receiving tPA or streptokinase the greater cost of tPA (10 times that of streptokinase) was sufficient to persuade both the Ontario Medical Association and the Ontario government not to provide hospitals with special funding for tPA until evidence supporting its superiority over streptokinase was forthcoming.[19] This decision was made in 1988, and in 1990 the results of a direct comparison of the two agents showed that tPA was not more effective.[17]

Choice of cost/QALY cutoff limits

The grades of recommendation divide technologies into those that cost (or save) less than $20 000/QALY, $20 000 to $100 000/QALY or more than $100 000/QALY. These arbitrary limits were chosen after a review of available economic evaluations and previously suggested guidelines.[20] Technologies that cost less than $20 000/QALY are almost universally accepted as being appropriate ways of using society's and the health care system's resources. Many technologies costing $20 000 to $100 000/QALY are provided routinely, but the availability of some is significantly limited (e.g., elective coronary artery bypass grafting[21]), and there is discussion about the appropriateness of others for various patient groups (e.g., bone marrow transplantation for those over 45 years of age[18]).

Two technologies can be classified in the same level and yet be very different in cost effectiveness. The administration of nonionic contrast media to people at high risk[14] ($23 000/QALY) and hospital hemodialysis[12] ($65 500/QALY) are both grade Ca technologies. However, the techniques of economic evaluation and quality-of-life assessment are not as yet standardized. The calculated cost/QALY can vary considerably depending on the techniques used. Also, reasonable sensitivity analyses may change the cost-effectiveness of an intervention greatly. Thus, we felt that narrowing the cost/QALY ranges of the various levels any further was not justified on the basis of currently available empirical evidence and analytical techniques.

Choice of clinical outcomes

QALYs have been suggested as an appropriate outcome measure for economic evaluations because they provide a "common yardstick" with which to compare the effectiveness of various interventions. QALYs are an index, a composite of the extra years of life provided by a therapy and the quality of that life, as measured by utilities.[22] By convention the utility scale runs from 0 to 1, 0 being equivalent to indifference between life and death and 1 being perfect health. Utilities can be estimated empirically by interviewing the investigators, the health care workers, members of society or the patients. The two most frequently used methods of measuring utilities in patients are the standard gamble and time trade-off techniques, although utilities can also be derived from multiattribute health indexes.[6,23] In general, measurements of patient or societal preferences are preferred for assessing health care technologies and forming policy.

Some limitations of utilities have recently been pointed out:[24–27] techniques are not standardized for measurement (this may yield different results in the same group of patients), utilities may be relatively unresponsive to a clinically important change detected by other outcome measures, and QALYs may not always accurately reflect the preferences of patients. Despite these reservations QALYs still seem to be a reasonable outcome measure for use in economic evaluations.

Some methodologically sound evaluations may not use QALYs; instead they describe the outcomes as discrete clinical events (e.g., myocardial infarction prevented or gastrointestinal hemorrhage avoided). It is unclear how such studies should be incorporated into the proposed grades of recommendation. At present, provided the outcome prevented is of major clinical importance, we suggest that an estimate of the utility associated with each event prevented (derived from asking either experts or patients) be used to calculate QALYs. However, it should be clearly indicated that QALYs were not assessed in the original study. As investigators gain more experience with QALYs it may become apparent that the utility associated with a clinical outcome (e.g., myocardial infarction prevented) is similar in different populations. If so, utilities would not have to be measured in all economic evaluations.

There are some interventions for which QALYs are difficult to measure. The calculation of cost-utility ratios for interventions that reduce short-term disabilities (e.g., the nausea, vomiting or pain associated with the use of contrast agents or postoperative recovery) is difficult, because these disabilities constitute such a small proportion of a person's entire life. Also, the utility derived from a reduction in uncertainty (e.g., the diagnosis of multiple sclerosis with the use of magnetic resonance imaging) cannot easily be incorporated into a full cost–utility analysis. An alternative approach is to determine which patients would be willing to pay for the reduction in disabilities or uncertainty. For example, in a sample of outpatients most were unwilling to pay $50 to decrease the risk of minor side effects from contrast media (pain, nausea, hives and flushing), but the median willingness to pay to reduce major and minor side effects from low-osmolar contrast media was $50.[28]

Incorporating the guidelines

The proposed guidelines offer direction concerning the strength of evidence for clinical and economic effectiveness associated with changes in health care policy. The guidelines are proposed as a necessary but not sufficient step in making decisions about the adoption and utilization of new technologies. The use of such guidelines would have a number of implications for both the conduct of clinical and economic evaluations and the forming of health care policy. These implications are briefly discussed below.

Timing of economic evaluations

The ideal time to evaluate the cost-effectiveness of a technology is before its widespread introduction into clinical practice, preferably at the same time as the randomized controlled trial is conducted to measure its clinical efficacy or shortly thereafter. This is rarely done. There are many reasons for this. Economic data are not required for the approval or licensing of most drugs and nonpharmaceutical technologies, and therefore there is no incentive for manufacturers to perform or encourage such evaluations (indeed, economic evaluations might indicate that the new technology is relatively cost-ineffective). Many physician researchers are interested in the clinical benefits of the technology but not the costs. Adding an economic evaluation to a clinical assessment can be expensive in terms of expertise, personnel and costs, and there is thus a reluctance to perform an economic evaluation before the clinical efficacy of the technology has been established.

However, as with many health care interventions, if the technology is found to be effective it is often incorporated into routine clinical practice before an economic evaluation can be done. This has occurred with recombinant human erythropoietin, which was recently licensed for use in patients with end-stage renal failure. The various provincial governments quite understandably felt obliged to decide on the level of funding for the drug before a complete economic evaluation was available, although they did have access to some economic evaluations funded by the pharmaceutical company. Lobbying from patients, nephrologists and the manufacturer made it impossible for the governments to delay their decision any longer, even though an economic evaluation was undertaken while the drug was being evaluated clinically.[29] However, the time required to perform the economic evaluation did not enable it to be peer-reviewed and published before the funding decision had to be made. In addition, some data needed for a complete economic evaluation will not be available for many years (e.g., employment status of recipients and the long-term cardiovascular effects of the drug).

Finally, the incremental cost-effectiveness of a technology at the point of its introduction may be very different from its cost-effectiveness later on, because as the technology gets better its incremental cost-effectiveness ratio improves (as is the case with liver transplantation).

Selection of technologies for economic evaluation

Like resources for the health care system itself, funds for evaluative studies are limited. A full-scale economic evaluation can add considerable cost to a clinical study, and it would be unfeasible to perform extensive economic evaluations on all new technologies. Such analyses are relatively unimportant when the condition is extremely rare and the total cost relatively minor. Economic evaluations should be performed if technologies are either extremely costly per case (e.g., bone marrow transplantation) or likely to be used by a considerable proportion of the population (e.g., nonionic contrast media) and are therefore potentially costly in aggregate.

To date, relatively few economic evaluations of diagnostic technologies (in terms of the equipment and the manner physicians use it) have been published. This is due in part to the difficulty in evaluating many of these technologies because they are used for a wide variety of indications, and the choice of the alternative diagnostic modality depends on the indication. However, studies are now becoming available that directly compare the diagnostic accuracy, sensitivity and specificity of different technologies. Recent examples include magnetic resonance imaging versus transrectal ultrasonography for the staging of clinically localized prostatic carcinoma[30] and magnetic resonance imaging versus computed tomography for patients with suspected lesions in the posterior cranial fossa.[31] Few of these studies provide accompanying economic evaluations, which should be encouraged in the future.

Given that many health care technologies are adopted and used in the absence of any evidence from systematic evaluation it is reasonable to question the usefulness of the proposed guidelines. It can be argued, however, that the early application of these guidelines could marginally improve the situation even when comprehensive evaluations are unavailable. The attempt to apply the guidelines will help to identify major gaps in the information on effectiveness, quality of life and costs. Even if it is impossible to organize a high-quality evaluative study to remediate the identified deficiencies, it should be possible to collect expert opinion systematically for each type of information and assemble it to assist in decision-making. The report would be classified as a level IV study, and the lack of strength of the evidence would then be included explicitly in the deliberations concerning the technology. The guidelines are important as both a means of grading evidence and a framework that identifies the types of information that would be useful in making sound decisions about adoption and utilization.

Total versus incremental costs

Our proposed classification system uses incremental cost–utility ratios rather than average ratios.[32] In an incremental analysis the differences in

Table 2: Introduction of low-osmolar contrast media as an example of an incremental cost–utility analysis

Treatment program	Cost per test, $	Utility (QALY)	Average cost–utility ratio,* $/QALY
Old	14.39	29.9986	0.48
New	36.98	29.9996	1.23

*The incremental cost–utility ratio for the new program was calculated by dividing the difference in the cost per test by the difference in the QALY ($22.59 ÷ 0.001 = $22 590/QALY).

both costs and consequences between new and old treatments are compared. This allows scarce resources to be allocated so that the maximum clinical benefit is provided.

In Table 2 the introduction of low-osmolar contrast media is used as an example of an incremental cost-utility analysis.[14] Two strategies are compared: the continued use of the old, high-osmolar media in all patients (the "old" program) and the use of the new, low-osmolar media only in patients at high risk of an adverse reaction (the "new" program). The average cost per patient of the contrast media as well as the average QALYs after contrast injection (assuming a life expectancy of 30 years with no adverse reaction) were calculated. The average cost-utility ratio of the new contrast media was $1.23/QALY ($36.98/29.9996). However, the incremental ratio was $22 600/QALY. Conceptually, the difference between these two ratios is that the incremental one reveals the cost per unit of the benefit of switching from one treatment strategy (usually already in use) to a new strategy, whereas the average ratio reflects the cost per benefit of the new strategy independent of alternative strategies. This example also illustrates that the old approach is not without cost — hence the need for an analysis of the costs and consequences of the old and new technologies.

However, decisions about and plans for the allocation of health care resources also consider the total costs of a technology. The number of patients undergoing long-term hemodialysis in a given year is less than the yearly incidence of myocardial infarction. Therefore, although two treatments may be about equal in terms of costs/QALY, the total cost for the treatment of myocardial infarction will be substantially greater than that for patients undergoing hemodialysis. The funding agency may be able to afford the latter but not the former. It will therefore be useful to include the number of patients who will benefit from the technology to assist in providing an estimate of the overall costs and benefits of the therapy.

Economic evaluations, ethics and politics

The introduction of a new technology is influenced by a combination of effectiveness, economics, ethics and politics. The relative contribution of each varies from situation to situation.

Economic evaluations deal with effectiveness and economics. However, society also needs to consider the ethical implications of health care policy when interpreting the results of a cost-benefit analysis.[33] For example, saving the life of a retired person may produce less direct economic benefits than saving the life of an employed person would.

The political process is the final pathway through which most decisions about the allocation of health care resources in Canada are made. Obviously factors other than effectiveness, economics and ethics come into play at this stage, and only a few will be briefly discussed here.

The perspective of an economic evaluation is extremely important. It is usually argued that a "societal" perspective, in which all costs and benefits associated with the introduction of a new program are considered, is the most appropriate. The ranking of cost-effectiveness ratios calculated from society's point of view should be neutral to value or distributional decisions. However, it is difficult for many people who decide on whether a program should be introduced to adopt an entirely societal point of view.[32] For example, the use of a cost-effectiveness analysis to forgo funding of a bone marrow transplant program will result in losses for patients with nonlymphocytic leukemia and gains for those who receive the alternatively funded interventions.

An institution may take its own point of view and rank cost-effectiveness ratios on which to base its allocation decisions. Alternatively some institutions may have particular goals that influence their resource allocation decisions independently of cost-effectiveness considerations. A hospital that sees itself as a tertiary care centre may wish to fund bone marrow transplantation rather than an immunization program. Physicians may stand to gain in financial terms and in terms of prestige if a program that they are associated with is funded. Thus, although a societal point of view is the most appropriate perspective many competing (and often legitimate) interests affect the allocation decision.

It is generally easier to withhold funding for a new technology than it is to withdraw funding from an existing one (even though the withdrawn funds could be spent more efficiently elsewhere). Now that universal precautions against HIV transmission have been introduced in some hospitals, it will be very difficult to withdraw them, even if they cost $565 000 per life saved. One example in which a more expensive and marginally safer technology has been withdrawn is the return to gentamicin as the aminoglycoside of choice in many hospitals.

Another influence on decision-making is the "identifiable beneficiary or victim." Programs that have an identifiable beneficiary or victim (e.g., a child with liver failure awaiting a transplant) often appear to receive higher priority than those that do not. Similarly, easily identifiable, "big-ticket" technologies (e.g., transplantation) receive much attention and discussion, whereas the frequently used and unnecessary "low-ticket" items (e.g., routine preoperative chest x-ray films in an asymptomatic patient)[34] may consume more resources but receive little attention.

It is almost universally accepted that the funds available for health care are limited. However, the exact amount that Canada should spend is not at all clear. In 1986 Canada spent 8.5% of its gross domestic product (GDP) on health care.[35] This placed Canada third (along with France) among members of the Organization for Economic Co-operation and Development.[35] Only the United States and Sweden spent more of their GDP on health care (11.7% and 9.1% respectively). In a society as wealthy as ours it is clear that if more health care funding was a societal priority and if there was the political will, the available funds could still be increased. Nonmedical programs such as education could also benefit from more funding, and some of these programs affect health. However, the point is that although society's overall resources are limited the proportion that is spent on health care could be increased.

The guidelines proposed in this paper do not directly address the issue of determining how much in aggregate Canada should spend on health care. Their main purpose is to assist in deciding which technologies and programs should be funded within any given budget by focusing on evidence of their clinical and economic effectiveness. The applications of these guidelines could, however, assist in the making of broader policies concerning overall budget priorities. If, for instance, most technologies were classified as grade A or B the implication might be that health care would warrant an increase in the aggregate level of expenditures. On the other hand, if most were classified as grade D this would not be considered evidence to support an increase in the health care budget.

A final point concerns the medical profession itself. The economic evaluations discussed here may appear to have a very little role to play in the care provided by individual physicians. Patients go to their physicians expecting the best possible care, without consideration of costs. However, most physicians make economic decisions in their practices daily when they budget their time (spending more of it with patients whom they think they can help) and select tests or treatments (choosing the cheaper of equally useful ones). Also, in their administrative functions (as advisers to the government, medical chiefs of staff or heads of departments) physicians have a societal responsibility to ensure that the limited resources available for health care yield the maximum benefit. Many physicians have specialized practices and quite naturally find themselves acting as advocates for a subgroup of patients (nephrologists are much more likely to press for funding of erythropoietin than for the increased availability of hip replacements). If the government is to be persuaded to consider seriously the results of economic evaluations when allocating scarce resources, then physicians must encourage the conduct of such studies in all areas of medicine (not just those that support their own narrow interests) and be willing to be guided by the results.

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Appendix 1: Criteria for assessing effectiveness, quality of life and costs in an economic evaluation

Effectiveness

Criteria for assessing the methodologic quality of studies that evaluate efficacy, meta-analyses and diagnostic tests have been published. The highest-quality evidence of efficacy is provided by a randomized controlled trial with low false-positive and false-negative error rates.[2] Alternatively, a meta-analysis in which only randomized controlled trials are included, a comprehensive search method is used to locate all the relevant studies, the variation in the findings of the studies are analysed, and the results of the primary studies are combined in an appropriate manner[36,37] can also provide the highest-quality evidence of efficacy. Some economic studies evaluate diagnostic tests. In such cases the highest-quality evidence is provided by a study in which there is an independent, blind comparison of two diagnostic tests, the sample of subjects with mild to severe disease is sufficiently large to allow narrow confidence limits on the resulting sensitivity, specificity or likelihood ratios, and the reproducibility of the test has been established.[38]

Quality of life

Quality of life should be estimated in an appropriate sample of people who have the disorder of interest with the use of measures whose validity, reliability and responsiveness to change have been demonstrated.[39] To allow comparison with cost–utility ratios for other interventions a utility measure (e.g., standard gamble, time trade-off and multiattribute utility measures) should be used that incorporates general health status rather than a disease-specific measure of quality of life.[40,41] However, if the economic attractiveness of various options in a particular program is being compared (e.g., treatment of end-stage renal disease) the use of disease-specific measures may be appropriate.

Costs

The highest-quality estimates of costs include those derived from direct measurement of resources used by the competing strategies in a sample of the population that used those resources. There are two components of costs: the volume of services used (e.g., hospital days, laboratory tests, physician visits) and the unit prices for each of those services. A high-quality study measures the volume of services and uses clearly identifiable unit prices that apply to the services (e.g., health ministry rates for physician services) and direct measurements of costs borne by institutions, including an appropriate method of allocating overhead.[42] Some investigators will have to use a sampling technique to estimate the quantity of individual services delivered under the competing strategies and use published sources for the unit prices.