Rationing potentially inappropriate treatment in newborn intensive care in developed countries

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Abstract

In newborn intensive care, parents sometimes request treatment that professionals regard as 'futile' or 'potentially inappropriate'. One reason not to provide potentially inappropriate treatment is because it would be excessively costly relative to its benefit.

Some public health systems around the world assess the cost-effectiveness of treatments and selectively fund those treatments that fall within a set threshold. In this paper, we explore the application of such thresholds to decisions in newborn intensive care, to explore: (1) when a newborn infant's chance of survival is too small; (2) how long treatment should continue; (3) when quality of life is too low and (4) when newborn infants are too premature for cost-effective intensive care.

This analysis yields some potentially surprising conclusions. Newborn intensive care may be cost-effective even in the setting of very low probability of survival, quality of life, for protracted periods of time or for the most premature of newborns.

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(Max 150 words)

1. Introduction

Health practitioners usually have a very strong desire to provide life-sustaining treatment (LST) to a newborn infant. Yet there are various situations when

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A. A newborn infant has a very severe congenital lung malformation. Doctors have attempted to stabilize the infant with specialized forms of breathing support; however, he has not responded. Doctors believe that there is a more than 95% chance that he will die despite maximal treatment. His parents are requesting that full active treatment (including, if needed, extracorporeal membrane oxygenation) be provided. *What chance of survival is too low to provide expensive life-support?*

B. A newborn infant, born extremely prematurely has had severe lung problems since birth. He has required support with a breathing machine in intensive care continuously for 6 months, and appears unable to breathe without support from the machine. Doctors and nurses in the intensive care unit feel that further treatment is futile, but his parents wish treatment to continue. *How long is too long to provide intensive life-prolonging medical treatment?*

C. A newborn infant has been diagnosed after birth with complex congenital heart problems that would usually be treated with major cardiac surgery. However, she also has been found to have a chromosomal disorder, and if she survives she will have severe intellectual disability. Specialists have suggested that surgery is not clinically appropriate, but the infant's parents are adamant that it should be attempted. *What level of disability is too great for life-saving surgery to be provided?*

D. A mother goes into premature labour several months before she is due to deliver. She has requested that doctors attempt to save her baby, but current guidelines do not recommend resuscitation. At this gestation there is a very low chance of survival if intensive care is attempted, infants require months of expensive treatment, and a significant proportion of survivors have long-term illness or impairment. *When is a newborn infant too premature for resuscitation to be attempted?*

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doctors could regard that treatment as potentially inappropriate. Consider the following cases:

Box 1: When are health professionals justified in declining to provide desired treatment?[1]

Professional guidelines endorse the idea that health professionals are not obliged to provide treatment that would be 'futile' or 'potentially inappropriate'.[1, 2] However, there is no existing agreement on how to define futile or inappropriate treatment, nor any clear way to use the concept to answer the questions outlined in the box.[3] There are often different views about what would be in the patient's interests, based on differing evaluations of the possible outcomes, as well as on different value-theories about what grounds such a judgment.[4] The difficulty in defining futility has led many ethicists to reject the concept, and dismiss its use in treatment decisions.[5-7]

However, distinct from concern for the patient's interests, a separate reason not to provide treatment may be because of concern for distributive justice and the need to limit expensive and scarce medical resources. Although most discussion about LST in newborn infants focuses on the child's best interests, (and perhaps on the interests and wishes of parents), resources are of central importance in intensive care, for newborn infants as for older patients.[8, 9] Unfortunately, it is sometimes necessary to ration potentially beneficial treatment on the grounds of distributive justice.[10]

One widely used way of deciding between different priorities for funding in a public health system is to compare their cost effectiveness. A commonly-used

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[1] These cases are composite versions of real cases encountered by DW

metric uses the concept of Quality-Adjusted Life Years (QALY). The QALY is a preference-based measure of health outcome that combines length of life and health-related quality of life in a single metric. Modelling based economic evaluations usually assign probabilities to branches emanating from chance nodes with endpoints of each pathway given values or payoffs, such as costs, life years or QALYs. This allows analysts to express the cost-effectiveness of new treatments in terms of incremental cost per QALY gained. Such calculations can be used to decide whether the incremental benefit of an individual treatment is sufficiently great, relative to the incremental cost, to provide it. Some countries and policy makers have used cost-effectiveness thresholds to efficiently and consistently decide between different priorities. In the UK, for example, interventions that cost less than a threshold level of £20-30,000 per QALY are usually funded by the National Health Service, while those that cost more than £30,000 are not usually provided.[11, 12]

There is considerable ethical debate about the use of cost-effectiveness thresholds, and QALYs for deciding between different treatments.[13-17] It is not the aim of this paper to review those arguments, nor to assess whether the incremental cost per QALY metric *should* be used to decide between medical treatments. Rather, the point is that cost-effectiveness thresholds are already widely used in many public health systems to decide between different treatments. If that approach is justified, on the grounds of consistency, it appears that these same thresholds should be applied to other medical interventions. What would be the implications of such an approach for decision-making in neonatal intensive care? One common objection to cost-effectiveness analysis is

that it might lead to rationing of life-saving treatment. The results of the analysis below might be used to inform debate about what the actual implications would be of applying cost-effectiveness thresholds to clinical decisions around potentially inappropriate treatment.

The focus here on the NICU allows us to set aside some issues that might be thought to make decisions more complicated for older individuals (e.g. it removes the question of whether priority should be given to those who have previously been worse off, or who have experienced a shorter life already). However, none of the analysis in this paper should be taken to imply that cost-effectiveness thresholds should be applied only or preferentially in the NICU. Indeed, one feature of standard cost-effectiveness thresholds suggests that resource limits far less often provide a justification for withholding treatment in the NICU than in adult or paediatric intensive care. If the duration of survival after intensive care is longer, the cost-effectiveness of providing life-sustaining treatment will be correspondingly greater.

Since the aim of this paper is to explore ethical questions, we will make some assumptions that will simplify analysis, but that would not be part of a formal economic evaluation. We will focus on the costs and effects of providing intensive care, compared with the option of withdrawing or withholding life-prolonging treatment (ie the clinical setting for a determination that treatment is potentially inappropriate). We will assume that infants not treated will die and make the simplifying assumption that an infant who dies in intensive care will not have generated economic costs or health consequences. Empirical data for

examples is drawn from a range of different countries and time points, reflecting the availability of data. We will convert currencies to UK pounds (using relevant purchasing power parities), but will not adjust for inflation over time. We will not apply discounting to future costs or the value of future life-gains. Finally, we will assume equal age-weighting for the potential health consequences of treatment (i.e. that a year of life saved for a newborn infant is equivalent to a year of life saved for an adult).

2. Low probability treatments

The general formula for assessing cost-effectiveness is given by the following:

$$Incremental\ Cost\ Effectiveness = \frac{\bar{C}_2 - \bar{C}_1}{\bar{E}_2 - \bar{E}_1} = \frac{\Delta C}{\Delta E}$$

where C_2 and E_2 refer to the mean cost and mean effectiveness of a comparison intervention, and C_1 and E_1 refer to the mean cost and mean effectiveness of the reference intervention. We are interested in comparing the alternatives of continuing intensive care versus withdrawal of intensive care. If we assume that all patients who have treatment withdrawn die (and that this is not associated with costs), the formula can be simplified:

$$Cost\ Effectiveness = \frac{\bar{C}_2}{\bar{E}_2}$$

The effectiveness of continuing intensive care will depend upon the mean probability of survival ($\bar{p}$), duration of survival (if the patient survives, $\overline{d_s}$) and his/her health-related quality of life (hereafter 'quality of life' for brevity) ($\bar{q}$).

Cost Effectiveness

$$= \frac{Cost \; (\bar{C})}{probability \; of \; survival \; (\bar{p}) \; x \; (duration \; of \; survival \; (\bar{d_s}) \; x \; quality \; of \; life(\bar{q}))}$$

In health care systems that use a fixed cost-effectiveness threshold, the formula for cost-effectiveness can be transformed. This can be used to estimate the Probability Threshold (P_T), where P_T is the lowest probability of survival for cost-effective life-saving treatment

$$P_T = \frac{\bar{C}}{CET \; x \; \bar{d_s} \; x \; \bar{q}}$$

$\bar{C}$ - mean cost of treatment

$\bar{p}$ - mean probability of survival

$\bar{d_s}$ - duration of survival (if the patient survives)

$\bar{q}$ - health-related quality of life

(These values could be the average value for a cohort of patients, or the expected probability/duration/quality for a single patient)

For example, for a newborn infant requiring 20 days of intensive care (at a cost of £1000/day), and predicted to survive with full quality of life for 70 years, the P_T would be ~1%. In other words, based on these assumptions it would be not cost-effective to provide this sort of treatment if there were a less than 1% chance of normal survival.

2.1 Probability threshold for ECMO

The above assumptions about the cost of treatment are fairly speculative. However, this general approach could be used to suggest an answer to the question in case A (Box 1). There has been considerable debate in the past about whether Extracorporeal Membrane Oxygenation (ECMO) is beneficial and should be provided.[18] More recently, debate has shifted to which infants should (or should not) be offered ECMO.[19-22] The average health care cost of ECMO from a large neonatal trial was approximately £30 000.[23] Using this figure, (and again assuming full health-related quality of life for survivors) the P_T (ECMO) would be 1.4%.[2]

One specific condition that is sometimes treated with ECMO is Congenital Diaphragmatic Hernia. It might be thought that ECMO is not cost-effective for infants with severe forms of this condition. A recent US study found the mean inpatient hospital cost of providing ECMO to infants with CDH was $193,000 (£115,000).[24] Using this figure, it would be potentially cost-effective to provide ECMO to infants with CDH who have a greater than 5% chance of survival. (Ongoing health care costs are not included in this estimate, and would be expected to influence the Probability Threshold.)

Infants with CDH who have unfavourable features on pre-natal ultrasound have a particularly low predicted survival rate (for example, a lung head ratio <1.0, in combination with liver herniation, implying a severe degree of pulmonary hypoplasia). It is sometimes thought to be 'futile' to provide treatment to this group of infants.[25] In one study, 3/27 infants with a lung head ratio <1 and liver

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[2] It is worth noting that ECMO is usually compared with continuing conventional intensive care (without ECMO), and there may be a significant chance of survival even without ECMO.

herniation survived (ie 11%).[26] This is therefore still potentially above the Probability Threshold for cost-effective treatment, and, it would arguably be justified to provide treatment despite finite resources.

2.2 Insights

How does this analysis help? First, treatment with low probability of survival may not be cost-effective. If resources are limited it may be reasonable not to provide treatment where that chance is below a certain threshold. Standard cost-effectiveness thresholds used elsewhere in medicine could be used to assess where this threshold might lie.

In neonatal intensive care, given a set of plausible assumptions (and ignoring for now questions of quality of life), the Probability threshold is likely to be very low. It may be cost-effective to provide treatment even if there is a 99% chance that the patient will die. Strikingly, even for infants with extremely severe congenital malformations and low chance of survival, (where clinicians sometimes regard treatment as potentially inappropriate) it could still be cost-effective to provide treatment.

3. Long duration treatment

When patients receive prolonged treatment in intensive care there may be significant concern about the costs and benefit of treatment.[27] Cost-effectiveness thresholds could be used to calculate the maximum duration of cost-effective intensive care, the Duration Threshold (D_T).

$$D_T = \frac{CET \; x \; \bar{d}_s \; x \; \bar{p} \; x \; \bar{q}}{\overline{C_d}}$$

$\bar{C}_d$ is the daily cost of treatment.

Based on this formula, we could estimate an answer to the question posed in case B about how long it may be appropriate to continue intensive care (Box 1). One older study suggested that 50% of newborn infants requiring mechanical ventilation for more than 6 months survived to age 3.[28] In a large US cohort study, 50% of extremely low birth weight infants ventilated for more than 4 months survived.[29] Based on that data, for infants with an estimated 50% chance of survival, the Duration Threshold for neonatal intensive care (assuming full duration of adult life and full quality of life) would be over 1000 days.

3.1 Duration threshold for ECMO

A similar analysis could be conducted for other intensive medical treatments. Table 1 presents an assessment of the duration of cost-effective ECMO for newborn infants, depending on the daily cost of ECMO, and the probability of survival (if ECMO is provided). This treatment is usually provided for periods of 1-2 weeks, but sometimes for longer than 1 month. This table suggests that it could be cost-effective to provide ECMO for as long as 6 weeks, even at a higher cost estimate, if there is a 25% chance of survival full life expectancy. This might be a realistic assumption. In one study of prolonged ECMO in children, 22% of children receiving more than 28 days of ECMO survived to discharge from hospital.[30] However, if there is a lower life expectancy, the Duration threshold

falls (Table 2). For patients with a 25% chance of survival (and life expectancy of 10 years), it may not be cost-effective to provide ECMO for more than 6 days.

[Insert Tables 1 and 2 here]

3.3 Insights

How does this analysis help? First, cost-effectiveness based criteria could be used to determine a threshold for the maximum duration of treatment. Analysis suggests that in neonatal intensive care prolonged mechanical ventilation or ECMO may be cost-effective even if long periods of treatment are required. Based on estimates of 50% survival, intensive care may be worth providing for several years to a newborn. Likewise, it may be cost-effective to provide 6-12 weeks of ECMO to a newborn infant.

These findings may be counterintuitive. One important limitation is the assumption of a normal lifespan. There is little or no evidence on the adult longevity of survivors of neonatal intensive care.[32] If duration of survival is reduced, that would reduce the duration of cost-effective treatment.

We have also assumed normal quality of life. That may be important, since many authors are critical of existing methods for quantifying quality of life – particularly if such measures were to be used in rationing health care.[13, 33, 34] However, a number of health care systems do incorporate measures of quality of life into cost-effectiveness assessments. What would be the implications of this for the treatment decisions in newborn intensive care?

4. Reduced Quality of Life

If survival is associated with reduced quality of life, and if were acceptable to incorporate quality of life into cost-effectiveness calculations, we could calculate a Quality Threshold (Q_T) – a minimum anticipated health-related quality of life for cost-effective intensive care.

$$Q_T = \frac{\bar{C}}{CET \ \times \ \bar{p} \ \times \ \overline{d_s}}$$

$\bar{C}$ – total cost of treatment in intensive care

For example, one large UK modeling study of the costs of treatment in neonatal intensive care found an average inpatient cost for extremely preterm infants admitted to NICU of £87552.[35] Based on this cost, the value of Q_T for an infant with a 50% chance of survival would be 0.08. (By comparison, the average value for health-related quality of life in a cohort of adolescents with cerebral palsy was 0.42).[36] In other words, it could be cost-effective to provide treatment to an extremely preterm infant even in the setting of substantially reduced predicted quality of life.

This includes only the acute in-hospital costs. There may be concerns about whether it is ethical to incorporate additional costs through childhood in decisions about providing neonatal intensive care. However, if the costs of ongoing treatment were included, we could calculate a further estimate of Q_T. In a UK analysis of costs for preterm infants, the average cost per year for children with severe disability (once they reached primary school) was approximately £12000.[35] Combining average acute and ongoing costs through childhood, and

focusing only on outcome to age 18, this would yield a value for Q_T of 0.47. Note that this value for Q_T is close to the average value for children with cerebral palsy, and to the value of health related quality of life used in some studies for surviving ex-premature infants with severe disability (0.4).[37] This suggests that provision of life-saving treatment to extremely preterm infants could be cost-effective, even in the setting of predicted certain severe disability.

4.1 Cardiac surgery for infants with severe disability

One example of this question is whether it would be potentially inappropriate for children with major chromosomal disorders such as Trisomy 18 to receive complex cardiac surgery.[38] Trisomy 18 is associated with a high rate of mortality (approximately 90% of infants die in the first year of life), but all surviving children have profound cognitive disability.[39] Should expensive cardiac surgery be provided to children with such severe disability? An assessment of the cost-effectiveness of treatment will depend on the value placed on survival with severe impairment. It will also depend on how long a child is predicted to live with and without cardiac surgery. That can be difficult to estimate, since available data are influenced by selection bias and non-treatment decisions.[40] From other data on children with disability, one estimate is that the median life expectancy (for children with severe cerebral palsy) is approximately 10 years for children with severe mixed disability, 15 years for children with severe motor disability, 35 years for children with severe cognitive disability.[41]

A recent paper from the US provides a useful list of in-hospital costs for a range of paediatric cardiac procedures.[42] We can determine from these values the

minimum quality of life that would render treatment cost effective (Table 3). (This is a conservative estimate, since some infants may survive without surgery).

[Insert Table 3 here]

From this table, major cardiac surgical procedures could be cost-effective for children with severe disability with a health-related quality of life of 0.4 or greater. If it were acceptable to include ongoing health care costs through childhood, the values for the Quality Threshold or the Survival Threshold would rise, implying that a better prognosis would be required for surgery to be potentially appropriate.

4.2 Insights

How does this analysis help? As already noted, the inclusion of quality of life in cost-effectiveness calculations raises questions about whether this would be unjustly discriminatory,[33, 43] but also about how to assess the quality of life of individuals born in states of disability. If quality of life is included in cost effectiveness calculations, some expensive treatments will be excluded. However, at least if basic treatments, and ongoing medical care are set aside from resource allocation decisions, some acute expensive interventions may be cost-effective despite severely reduced quality of life – for example cardiac surgery for complex congenital heart disease.

5. Intensive care in the setting of reduced probability of survival, high cost, and quality of life

Our analysis has artificially isolated individual variables. However, often questions about resuscitation raise a mix of issues. Treatment may be highly expensive acutely and in the long term. There is a reduced chance of survival. Surviving children may have reduced quality of life. For example, this potentially applies to infants at the margins of viability.

5.1 Should resuscitation be provided for 22-week gestation infants?

In the United States, there is wide variation in the rates of active treatment for extremely premature infants born at 22 weeks of gestation,[44] which appears to reflect a judgment by some that treatment is potentially inappropriate. In the UK, resuscitation is not recommended for infants born before 23 weeks' gestation.[45] Although economic costs were not a factor cited in the development of that policy, this view might be justified if it were too expensive to treat infants this premature relative to the outcome.

The relative paucity of data (and the small number of infants actively treated), makes it difficult to assess the costs of treatment for 22 week infants.[46] However, it may be possible to extrapolate from a slightly less immature cohort. Recent modelling, based on US data, incorporated estimates of survival rates, acute hospital and long-term care costs as well as reduced quality of life in a proportion of survivors. This analysis suggests that selective or routine resuscitation and intensive care falls within cost-effectiveness thresholds (of

$100,000/QALY) for 23 week infants as long as the chance of survival is above 5%.[47] If the costs are similar, that may imply that resuscitation is cost-effective for 22 week infants, since the actual rates of survival at this gestation for infants admitted to intensive care appears closer to 20%.[44] (In fact, the costs per infant may be *lower* in more immature infants, since a high proportion of infants die early in the neonatal period and do not incur substantial costs.[46]).

This appears to suggest that based on available data, provision of resuscitation and intensive care is cost-effective even at gestations where treatment is often withheld. However, it may not be cost-effective to provide intensive care to subgroups of extremely premature infants, for example with very low chances of survival (<5%).

6. Conclusions

In this paper, we have explored how cost-effectiveness analysis could be applied to clinical questions about when treatment is potentially inappropriate on the grounds of excessive cost relative to benefit. We have not argued that cost-effectiveness should be applied in this way, but aimed to assess what the implications would be for developed countries if it were acceptable to ration treatment in this way. Although we have derived some specific answers about where the thresholds might lie, these should be seen as a starting point for debate rather than being applied to clinical practice. The underlying assumptions – about the costs of treatment, about the outcome of therapy, and about the cost-effectiveness threshold, would need to be assessed and potentially modified in a particular situation. For many of these questions in newborn intensive care,

there is limited available data on the costs or on the outcome of treatment –
indicating the need for further careful research to inform decisions.

We have used a particular cost-effectiveness threshold in the above calculations,
however, particular health systems may use a higher or lower threshold.
Alternatively, they may choose to apply what is sometimes called the 'rule of
rescue', [48] [49] and use a higher threshold for intensive care than for other medical
treatments. If that were the case, the lessons learned from the foregoing analysis
are likely to still apply – though the specific thresholds would vary. Table 4
provides corresponding answers to some of the questions asked in the cases at
the start of this paper at higher (and lower) levels of the cost-effectiveness
threshold.

[Insert Table 4 here]

The foregoing analysis highlights some tentative conclusions that may appear
counterintuitive or challenge existing practice. First, the potential long survival
following newborn intensive care means that cost-effectiveness-derived
thresholds in that setting will yield more treatment, longer treatment, and
treatment in a wider range of cases than is the case for older children or adults.
This may conflict with some current views about whether or not resuscitation
should be provided to some of the sickest and most premature newborn infants.
Conversely, it may highlight an apparent disconnect between current practice
and ethical theory, since there is evidence that treatment thresholds in
paediatric intensive care are more generous than in newborn intensive care (in

the PICU, doctors appear to be less inclined to limit treatment in the face of poor prognosis compared with NICU).[50] One possibility, not discussed in this paper, is that different value is placed on saving lives at different points in the life-span.[51] If such an approach were followed, that would apply a lower (or a higher) cost-effectiveness threshold to newborn infants.

The most controversial feature of applying cost-effectiveness thresholds to intensive care is the apparent implication that life-sustaining treatment would be denied to some patients with predicted disability. The foregoing analysis suggests that if it is justified to include quality of life in cost-effectiveness analysis, in newborn intensive care treatment may be limited on resource grounds only where future quality of life is predicted to be very low. Depending on whether or not long-term care costs are included, major interventions are still potentially cost-effective, even in the setting of certain severe predicted disability.

One fear that is sometimes expressed about rationing in general, and cost-effectiveness analysis in particular, is that it would lead to withholding of life-sustaining treatment from many patients who stand to benefit. The above analysis suggests that this is not the case, at least in the context of newborn intensive care.

The application of cost-effectiveness analysis may provide an ethically defensible way to determine when treatment would be potentially inappropriate. However, it may also, in a significant number of cases, challenge and contradict existing implicit rationing; it may support and promote access to desired medical treatment.

Practice Points

Research Directives

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Probability of survival	Duration Threshold - Days (Daily cost of ECMO £6000)	Duration Threshold - Days (Daily cost of ECMO £12000)
0.1	35	18
0.25	88	44
0.5	175	88
0.75	263	131

Table 1: Duration threshold for maximum cost-effective ECMO at different values for the probability of survival. Assuming that if ECMO is withdrawn prematurely that the patient will not survive. Based on daily costs of ECMO as a bridge to transplant for children of £6-12000 per day.[31]

Life expectancy	D_T
70	44
60	38
50	31
40	25
30	19
20	13
10	6

Table 2 Duration threshold for ECMO (at a daily cost of £12000) based on predicted life-expectancy, for a patient with 25% chance of survival.

	Procedure cost (USD)	Procedure cost (pounds)	$Q_T(10)$	$S_T(0.4)$
Atrial Septal Defect repair	25499	15554	0.05	1.3
Ventricular septal defect repair	33679	20544	0.07	1.7
Tetralogy of Fallot repair	44318	27034	0.09	2.3
Fontan	51464	31393	0.10	2.6
Arterial Switch	94902	57890	0.19	4.8
Truncus repair	133006	81134	0.27	6.8
Norwood	165168	100752	0.34	8.4

Table 3: Median costs of cardiac surgery in childhood[42] and the Quality/Survival thresholds for children with either predicted reduced lifespan, or predicted reduced quality of life, ignoring ongoing health care costs.

$Q_T(10)$ – Minimum predicted quality of life consistent with cost-effective treatment, assuming predicted survival of 10 years

ST(0.4) - Minimum duration of survival for cost-effective treatment, assuming a quality of life of 0.4

Incremental Cost-effectiveness threshold (pounds)	10 000	20 000	**30 000**	50 000	100 000
What probability of survival is too low to provide ECMO? (see section 2) – Case A	4.2%	2.1%	**1.4%**	0.8%	0.4%
What duration of mechanical ventilation is too long in neonatal intensive care? (see section 3) – Case B	350 days	700 days	**1050 days**	1750 days	3500 days
What is the lowest quality of life to provide a Fontan repair? (see section 4) – Case C	0.3	0.15	**0.1**	0.06	0.03

Table 4. Summary of thresholds for cost-effective treatment, with alternative answers at different cost-effectiveness thresholds. Assumptions are described in the relevant sections of the text. Answers in bold are those provided in the text for a standard cost-effectiveness threshold of £30,000/QALY.