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Notions of "Value" in Healthcare

Aggregate Distributional Cost-Effectiveness Analysis of Health Technologies

James Love-Koh, PhD,* Richard Cookson, PhD, Nils Gutacker, PhD, Thomas Patton, PhD, Susan Griffin, PhD

Centre for Health Economics, University of York, York, England, UK.

ABSTRACT

Background: Health inequalities can be partially addressed through the range of treatments funded by health systems. Nevertheless, although health technology assessment agencies assess the overall balance of health benefits and costs, no quantitative assessment of health inequality impact is consistently undertaken.

Objectives: To assess the inequality impact of technologies recommended under the NICE single technology appraisal process from 2012 to 2014 using an aggregate distributional cost-effectiveness framework.

Methods: Data on health benefits, costs, and patient populations were extracted from the NICE website. Benefits for each technology were distributed to social groups using the observed socioeconomic distribution of hospital utilization for the targeted disease. Inequality measures and estimates of cost-effectiveness were compared using the health inequality impact plane and combined using social welfare indices.

Results: Twenty-seven interventions were evaluated. Fourteen interventions were estimated to increase population health and reduce health inequality, 8 to reduce population health and increase health inequality, and 5 to increase health and increase health inequality. Among the latter 5, social welfare analysis, using inequality aversion parameters reflecting high concern for inequality, indicated that the health gain outweighs the negative health inequality impact.

Conclusions: The methods proposed offer a way of estimating the health inequality impacts of new health technologies. The methods do not allow for differences in technology-specific utilization and health benefits, but require less resources and data than conducting full distributional cost-effectiveness analysis. They can provide useful quantitative information to help policy makers consider how far new technologies are likely to reduce or increase health inequalities.

Keywords: distributional cost-effectiveness analysis, economic evaluation, health equity, health inequality, health technology assessment

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Introduction

Health inequality is an important policy concern in health systems across the globe.[1,2] England is no exception, with a number of high-profile reports highlighting the disparities in health status between rich and poor members of society.[3-5] National policy makers and local third-party payers in the English National Health Service (NHS) have a statutory duty to "have regard to the need to reduce inequalities in the benefits received by patients," which was formalized in the Health and Social Care Act 2012.[6]

In this article we propose a methodology for conducting quantitative health inequality impact assessment for new health technologies using aggregate data on disease prevalence and the cost and health impacts of interventions. This methodology can be applied in all jurisdictions where health policy makers are concerned with reducing health inequalities, subject to data availability. We demonstrate this for one part of the English health system that influences inequalities in the benefits received by patients: the single technology appraisal (STA) process used by the National Institute of Health and Care Excellence (NICE).

The evaluative framework used by NICE, cost-effectiveness analysis (CEA), has so far focused primarily on the cost-effectiveness of treatments in producing health outcomes relative to cost. Under NICE guidelines, health benefits are measured in terms of quality-adjusted life years (QALYs), a health metric that accounts for quality and length of life. Costs, meanwhile, are treated as health losses associated with forgone health services because funding services from the NHS budget commit resources that could have otherwise been used to provide alternative

* Address correspondence to: James Love-Koh, PhD, Centre for Health Economics, Alcuin A Block, University of York, York YO10 5DD, England, United Kingdom.
Email: james.love-koh@york.ac.uk

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healthcare interventions. These health opportunity costs can be represented by the value of existing NHS activities in terms of the cost to produce one QALY. A new intervention with an incremental cost per QALY gained (ICER) lower than the cost per QALY of forgone alternatives would there be expected to increase the total health produced from NHS resources.

By only dealing with average health gains and losses, distributional consequences are ignored. Health inequality impacts of new interventions are not quantitatively analyzed or formally incorporated into decisions made by NICE appraisal committees. Distributional cost-effectiveness analysis (DCEA) is a framework that has sought to address this shortcoming by extending traditional CEA[7] to estimate health benefits and losses by social groups of interest (ie, by socioeconomic status, age, or sex), which are then combined to describe a population distribution of net health effects. These net effects can then be added to the baseline distribution of expected lifetime health to understand how health inequality might change as a result of funding decision.

Full DCEA requires the distribution of direct health benefits to be estimated from a decision analytic model or trial-based analysis using parameter estimates specific to socioeconomic groups. This article outlines a simplified version that takes the average gain from a CEA, scales it up using patient population numbers, and disaggregates the population-level benefits according to the social patterns observed in healthcare utilization data for the targeted disease.

Our framework provides healthcare decision makers and stakeholders with an evidence-based technique for evaluating whether new interventions can help to achieve the objective of health inequality reduction, which can be used when conducting a full DCEA is not practical or feasible. We apply this approach to a sample of 27 interventions appraised by NICE over a 3-year period.

Methods

Overview

Our analysis used three sources of data, as shown in Figure 1. Mean incremental costs and benefits were extracted from the manufacturer's submission to NICE along with patient population estimates to calculate population-level effects. Benefits were distributed between socioeconomic groups according to healthcare utilization patterns observed in Hospital Episode Statistics (HES) for the relevant disease, identified by a 3-digit International Classification of Disease (ICD) code. Costs were converted into health losses using a recent estimate of the marginal productivity of the NHS, disaggregated into age, sex, and socioeconomic groups.[8,9] The difference between the benefits and costs provided net effects over the distribution of social groups. These were then added, by both individual STA and collectively, to a baseline distribution of lifetime health that was also measured in terms of QALYs[10] to assess the impact on health inequality.

Data and variables

NICE technology appraisal data

Health benefits, costs, and target population were extracted for recommended treatments and their comparators within NICE STAs issued between January 2012 and November 2014. Although the Appraisal Committee bases recommendations on its preferred or most plausible set of estimates from the range of scenario and sensitivity analyses presented, these are often not made explicit in the guidance documents and are not consistently described across all STAs. The independent Evidence Review Group (ERG) analyses also could not be used because they did not systematically report incremental costs and benefits separately. Instead, we used the expected costs and benefits from the manufacturers' base case scenario because these are consistently reported across STAs.

Information was obtained from guidance documents, manufacturers' cost-effectiveness submissions, and costing templates via the NICE website. We excluded STAs from our analysis if the appraisal committee did not recommend the treatment for adoption into the NHS, it was an update of a previous appraisal that did not change the adoption decision, or relevant information was withheld on the grounds of it being *commercial in confidence*. The latter was typically the case when manufacturers negotiated a patient access scheme with the Department of Health that allowed patients access to the new treatment at a reduced price. Where multiple treatments recommended for the same condition were appraised separately, these were treated as independent and no attempt was made to combine the results. Health benefits were expressed as QALYs. Costs and health benefits had been discounted at a rate of 3.5% in line with NICE's methods guidance.

Information on the number of patients in England who would be eligible for treatment was extracted from the costing templates provided by NICE. The calculation of population net health benefits assumed that the intervention would be provided to all eligible patients, which is the maximum impact consistent with the recommendation decision.

Hospital episode statistics

HES is a database containing information on all NHS-funded activity in public and private hospitals in England. We extracted data on patients' sex, primary diagnosis (ICD-10), and postcode, where the latter was used to assign the patient a deprivation score using the 2004 Index of Multiple Deprivation (IMD). The IMD is an area-based measure that calculates a score for all 32 482 small areas in England, incorporating information on 7 dimensions of deprivation (income, employment, health, education, housing, living environment, and crime).[11] IMD scores were grouped into quintiles and assigned to patients according to their small area of residence. These groupings were used as our measure of socioeconomic status.

We used 2 years of inpatient HES data (financial years 2011 and 2012) to count the number of episodes associated with 1562 3-digit ICD-10 codes that make up NHS spending and then disaggregated them by sex and IMD group.

Health opportunity costs

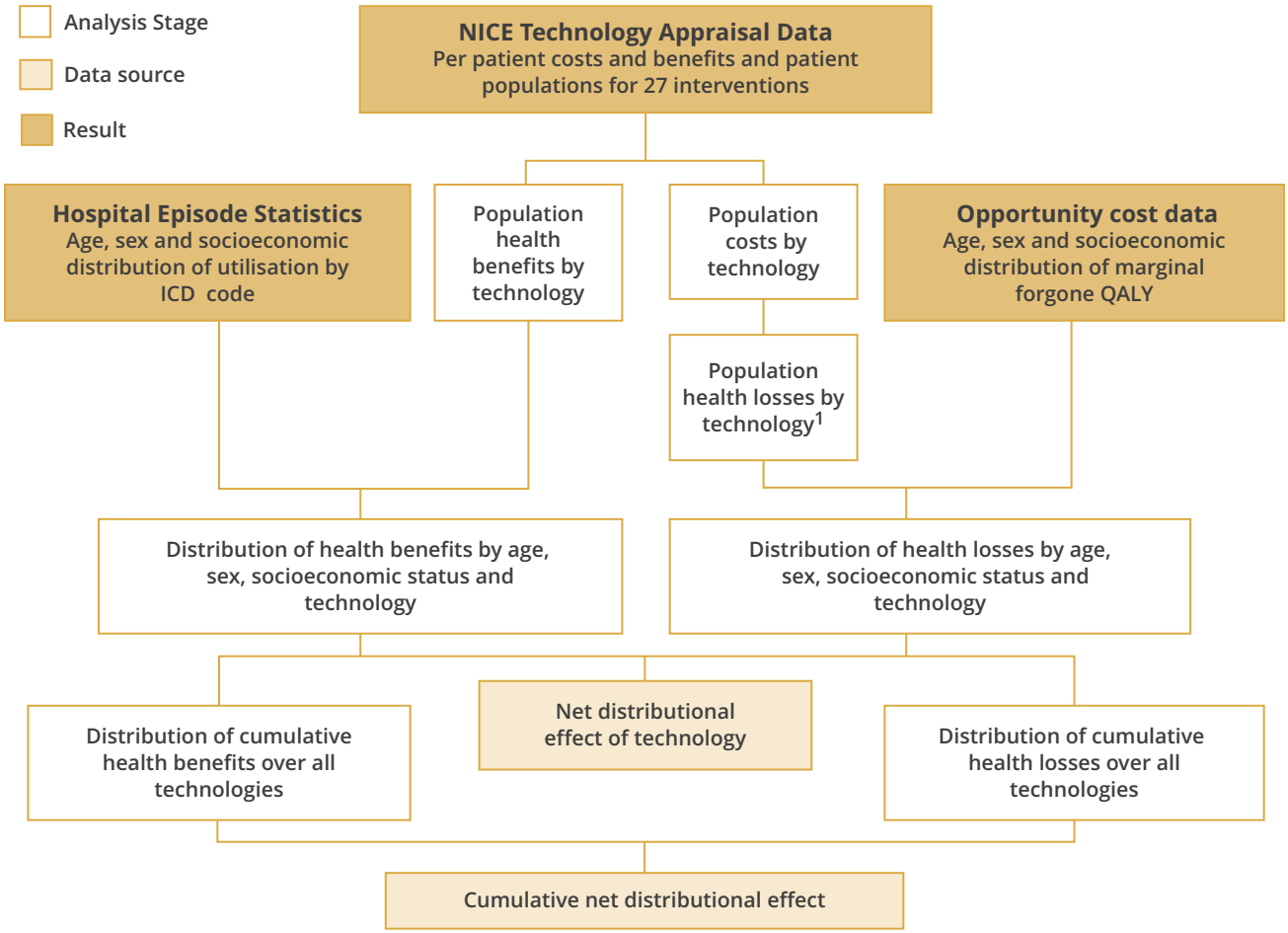
Costs were converted into health losses using a value representing the expected cost per QALY of forgone alternatives in the English NHS of £12 936, taken from the most recent empirical analysis of the health system's marginal productivity.[8] This is lower than £20 000, the lower bound of the threshold range adopted by NICE, which incorporates concerns relating to access to new treatments as well as opportunity cost.[12] We also used estimates of how these forgone QALYs are distributed using the results of Love-Koh et al[9] who used disease-specific healthcare utilization data to disaggregate the results of Claxton et al[8] to obtain the share of health opportunity costs by sex and socioeconomic status. They found that 26% of health losses are incurred by the most deprived quintile compared with 14% for the least deprived. Health losses also fell more heavily on women (55%) than men (45%).

Analysis

Modeling net health changes

Incremental costs and QALYs were calculated between new interventions and each of the comparator treatments for every

Figure 1. Influence diagram demonstrating how our data sources are combined to estimate the net distributional effect of interventions.



ICD indicates International Classification of Disease; NICE, National Institute of Health and Care Excellence; QALY, quality-adjusted life year. [1]Costs are converted into health losses using an estimate of the cost-per-QALY of forgone alternatives from Claxton and colleagues[8] of £12 936.

STA. Costing templates for each STA show how current practice at the time included a mix of the comparators and provide estimates of market share (the number currently receiving each comparator). We used these data to calculate population-level costs and QALYs, weighted over J comparators in each STA t. The potential net population benefit of the new intervention in that STA, NPB_t, is then:

$$NPB_t = \sum_{j=1}^{J} h_{tj}p_{tj} - \sum_{j=1}^{J} \frac{1}{k}(c_{tj}p_{tj}) = PB_t - PC_t$$

where h_{tj} is the incremental QALYs, p_{tj} the patient population, c_{tj} the incremental costs, k the cost-per-QALY of forgone alternatives, and PB_t and PC_t the population benefits and health opportunity costs, respectively. By dividing through PB_t and PC_t by $\sum_j p_{tj}$, we obtain the "blended" incremental health and costs per person for each technology.

The next step involves estimating the health benefits likely to be accrued for different sex and socioeconomic groups in each appraisal. Each STA is allocated to an ICD code (or group of codes) via its respective disease area (see Table 1). The distribution of healthcare utilization by sex and socioeconomic group for each disease is then extracted from HES. We use this information to quantify the distribution of the total population benefits (PB_t) across subgroups.

We then obtain the net benefits from implementing each technology by subgroup:

$$NSB_{tds} = PB_t z_{tds} - PC_t u_{ds}$$

where NSB_{tds} is the net health benefit accruing to deprivation group d and sex s from STA t, z_{tds} are the proportions estimated from HES described above, and u_{ds} are the proportions of health opportunity cost accruing to each subgroup. A worked example demonstrating the calculations involved in estimating the distribution of net population benefits for technology appraisal (TA) 260 can be found in Appendix B in the supplemental materials (found at https://doi.org/10.1016/j.jval.2019.03.006).

Inequality impacts

To model changes in lifetime health inequality, we took estimates of quality-adjusted life expectancy (QALE) at birth by sex and IMD quintile group and added the net health benefits per subgroup for each STA (NSB_{tds}) to the lifetime QALYs for

Table 1. Sample of single technology appraisals (STAs) used in the analysis.

TA	Technology	Disease area (ICD code)	Inc. health	Inc. costs	Inc. ratio	NHB	Patients
245	Apixaban	Thromboembolism (I82)	0.035	−£244	Dominant	0.054	91 100
248	Exenatide	Type 2 diabetes (E11)	0.085	−£282	Dominant	0.106	39 765
249	Dabigatran etexilate	Atrial fibrillation (I48)	0.188	£1410	£7501	0.079	137 124
252	Telaprevir	Hepatitis C (B18)	0.974	£10 930	£11 226	0.129	17 456
253	Boceprevir	Hepatitis C (B18)	1.351	£8508	£6296	0.694	17 456
254	Fingolimod	Multiple sclerosis (G35)	0.693	£19 012	£27 429	−0.777	2449
256	Rivaroxaban	Atrial fibrillation (I48)	0.039	£740	£18 974	−0.018	137 124
260	Botulinum	Migraine (G43)	0.090	£543	£6033	0.048	35 180
261	Rivaroxoban	Deep vein thrombosis/pulmonary embolism (I26)	0.019	−£258	Dominant	0.039	39 828
265	Denosumab	Bone cancer (C40, C41)	0.007	−£1351	Dominant	0.111	86 656
266	Mannitol	Cystic fibrosis (E84)	1.570	£46 935	£29 895	−2.058	200
267	Ivabradine	Coronary heart disease (I50)	0.280	£2376	£8486	0.096	10 466
275	Apixaban	Atrial fibrillation (I48)	0.241	£1326	£5498	0.139	452 463
283	Ranibizumab	Macular edema (H35)	0.245	£1581	£6457	0.123	10 663
287	Rivaroxoban	Thromboembolism (I82)	0.060	£591	£9821	0.014	18 497
288	Dapagliflozin	Type 2 diabetes (E11)	0.247	−£99	Dominant	0.254	155 086
292	Aripriprazole	Bipolar I disorder (F31)	0.007	−£686	Dominant	0.060	20
297	Ocriplasmin	Vitreomacular traction (H43)	0.086	£1781	£20,777	−0.052	954
303	Teriflunomide	Multiple sclerosis (G35)	0.305	−£6200	Dominant	0.784	9780
306	Pixantrone	B-cell lymphoma (C85)	0.200	£4759	£23 796	−0.168	1650
312	Alemtuzumab	Multiple sclerosis (G35)	1.101	−£3424	Dominant	1.366	6906
315	Canagliflozin	Type 2 diabetes (E11)	0.111	£547	£4939	0.068	711 444
318	Lubiprostone	Chronic idiopathic constipation (K59)	0.001	−£20	Dominant	0.002	25 500
320	Dimethyl fumarate	Multiple sclerosis (G35)	0.240	£31 979	£133 523	−2.233	4891
322	Lenalidomide	Myelodysplastic syndrome (D46)	0.720	£17 677	£24 551	−0.646	200
325	Nalmefene	Alcohol dependence (F10)	0.071	−£397	Dominant	0.102	57 820
326	Imatinib	Gastrointestinal stromal tumors (D37)	1.430	£22 931	£16 036	−0.343	170

Note. The incremental costs and benefits are "blended" estimates, calculated by combining the estimates for each technology over their relevant comparators and combining them into one figure, weighted by their respective market share.
ICD indicates International Classification of Disease; Inc., incremental; NHB, net health benefit; TA, technology appraisal.

each respective subgroup to obtain a postintervention health distribution:

$$Q\grave{}_{tds} = Q_{ds} + \frac{NPB_{tds}}{n_{ds}}$$

where $Q\grave{}_{tds}$ and Q_{ds} are the health distributions with and without the technology, respectively, and n_{tds} is the population of the sex and socioeconomic subgroup. Combining each subgroup's QALE estimate with its respective population figure and ordering the whole population from least to most healthy yields univariate distributions of pre- and postintervention health.

Inequality measures

We used these health distributions to measure and evaluate changes in health inequality and health-related social welfare. Two inequality measures were estimated: the slope index of inequality (SII) and the relative inequality index (RII). The SII measures absolute inequality; an SII of 10 means that the healthiest in the population experience 10 more lifetime QALYs than the least healthy. RII summarizes the relative difference: an RII of 0.1 would mean that the healthiest experience 10% more lifetime QALYs than the poorest. The inequality impact is the difference between the values pre- and postintervention: we reported the reduction in SII/RII so that a positive value means that health inequality has reduced.

Interventions were plotted on the health equity impact plane to show the joint effects on health inequalities (in terms of SII reduction) and total population health. Interventions that had a positive incremental net health benefit increased total health and fell in the north of the plane. Interventions that reduced absolute inequality as measured by the SII fell in the east of the plane. Tradeoffs between inequality reduction and total health improvement occurred for interventions falling in the northwest and southeast quadrants.

Impacts on total population health and health inequality were combined into a single index measure of health-related social welfare using the Atkinson and Kolm social welfare functions. Both measure social welfare change solely as a function of (1) mean health and (2) health inequality. The strength of social preferences for reducing health inequalities is explicitly captured through an "inequality aversion" parameter. Interventions that provide greater benefits to the worst off will yield greater health-related social welfare improvements as this

parameter increases. The Atkinson index, A_ε, measures inequality relatively and is given by:

$$A_\varepsilon = 1 - \left[\frac{1}{N}\sum_{i=1}^{N}\left(\frac{Q_i}{\overline{Q}}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

where N is the total population, Q_i is the QALE estimate of the ith individual, $\overline{Q}$ is the mean QALE, and ε the inequality aversion parameter that quantifies the concern for relative inequality. Alternatively, the Kolm index, K_α, incorporates inequality on an absolute scale, where absolute inequality aversion is represented by the parameter α:

$$K_\alpha = \left(\frac{1}{\alpha}\right)\log\left(\frac{1}{N}\sum_{i=1}^{N} e^{\alpha[\overline{Q}-Q_i]}\right)$$

Our analysis uses estimates of 10.95 for ε and 0.15 for α, based on a survey of general public in England.[13] The inequality aversion parameter does not define a set of fixed weights for different groups; rather, they vary according to the level of baseline of health. Given the current baseline inequality in England, an Atkinson parameter of 10.95 implies that a marginal QALY gained by the poorest fifth of people is worth seven times more than a marginal QALY gain within the richest fifth. Social welfare is calculated by combining each index with the mean level of health in the distribution to obtain the "equally distributed equivalent" (EDE) level of health:

$$EDE_{A,\varepsilon} = N(1-A_\varepsilon)\overline{Q}$$

$$EDE_{K,\alpha} = N\left(\overline{Q}-K_\alpha\right)$$

where N is the size of the general population and $EDE_{A,\varepsilon}$ and $EDE_{K,\alpha}$ are the Atkinson and Kolm welfare scores, respectively. The equally distributed equivalent is the level of population health (expressed in QALYs) in a completely equal distribution that yields an equivalent amount of social welfare to the distribution being evaluated. We calculated the $EDE_{A,\varepsilon}$ and $EDE_{K,\alpha}$ pre- and post-intervention, with the difference indicating the change in health-related social welfare. Comparing the incremental QALYs to the incremental EDE provides the QALY valuation of any change in inequality. For example, if an intervention increases population health by 100 000 QALYs and increases EDE by 101 000 QALYs, the reduction in health inequality attributed to the intervention is valued at 1000 QALYs.

Sensitivity analysis

We investigated the possibility that the incremental costs and QALYs cited in the manufacturer's submissions may be biased in favor of the new treatment.[14] To do this, we used results of Versoza et al,[15] who compared the differences between the incremental cost-effectiveness ratios (ICER) estimated by manufacturers with those of the Evidence Review Groups (ERGs) employed to evaluate the manufacturer's analyses for the period 2003 to 2015. They found that the manufacturer estimates were £6200 lower on average than those produced by the ERGs. We used this number to adjust our data by calculating the additional cost required to increase the ICER by £6200 and the reduction in benefit required to increase the ICER by £6200. Interventions that are health improving and cost saving (or "dominant") do not produce ICERs for adjustment. For these interventions, we used regression analysis on the sample of interventions with ICERs to predict adjustments based on the manufacturer costs/QALYs (for more detail see Appendix A in the supplemental materials found at https://doi.org/10.1016/j.jval.2019.03.006).

One-way sensitivity analyses are also conducted to explore the effect of the inequality aversion parameter and the size of the health opportunity costs on results.

Results

Descriptive statistics

Of the 68 STAs listed on the NICE website during the analysis period, a total 27 met the inclusion criteria and contained the required data on predicted incremental health, costs, and population (summarized in Figure A1 in the supplemental materials found at https://doi.org/10.1016/j.jval.2019.03.006). "Blended" estimates of incremental health and costs, weighted by market share across comparators, are reported for each technology in Table 1. Incremental health benefits ranged from 0.01 to 1.57 QALYs per person and incremental costs ranged from savings of £6200 to additional costs of £46 935. In terms of net health, these blended estimates yielded 10 dominant interventions, whereas the highest ICER of £133 523 was reported for dimethyl fumarate for multiple sclerosis.

The distributions of healthcare utilization for each disease area extracted from HES are provided in Table A1 in the supplemental materials (found at https://doi.org/10.1016/j.jval.2019.03.006). The average proportion of health benefits allocated to the most advantaged fifth was 16.2%, compared with an average of 23.4% in the most disadvantaged. On average, the interventions provided 1.56 times as many health benefits to the most deprived fifth versus the least deprived fifth (range 0.95-3.38). The net population benefits are shown in Table 2. Nineteen interventions had a positive net health impact, the highest of which was apixaban for atrial fibrillation, with 62 745 population QALYs.

Health inequality impacts

Fourteen technologies had a lower postintervention SII compared with preintervention, indicating that health inequality has been reduced. The biggest reduction of 0.00056 was found for boceprevir for hepatitis C. Of the 13 technologies that increased inequality, the largest increase in SII of 0.00085 was for apixaban for atrial fibrillation.

The health equity impact plane (Figure 2) showed that all 14 inequality reducing interventions were also health improving. Of the 13 inequality increasing interventions, 8 reduced population health. The remaining 5 interventions involved a tradeoff between increasing health gain and increasing inequalities.

Social welfare analysis indicated that the 5 interventions associated with tradeoffs between health improvement and health inequality were estimated to have a positive impact on social welfare (Table 2). The intervention yielding the largest social value of reducing inequality was boceprevir for hepatitis C. The potential inequality reductions for this intervention were equivalent to 4818 additional QALYs on top of the incremental health gain of 12 109 QALYs (at Atkinson ε = 10.95). Across STAs, the potential population QALY and EDE QALY increases were 207 000 and 217 000, respectively—yielding a total additional social value equivalent to 10 000 QALYs.

Sensitivity Analysis

The effects of changing base case assumptions on the equity impact plane location of interventions are shown in Table 3. When the ICER increase of £6200 is attributed to higher costs, the number of interventions assumed to improve health is unaltered

Table 2. Health, inequality, and social welfare impact of each technology.

TA	Technology	Population NHB	Inequality measures		Social welfare measures	
			ΔSII ($\times 10^4$)	ΔRII ($\times 10^4$)	$\Delta EDE_{K,\alpha}$	$\Delta EDE_{A,\varepsilon}$
245	Apixaban	4917	0.769	0.0145	5243	5360
248	Exenatide	4230	0.463	0.0090	4621	4741
249	Dabigatran etexilate	10 834	−2.595	−0.0312	8903	8979
252	Telaprevir	2248	3.001	0.0431	4485	4728
253	Boceprevir	12 109	5.509	0.0840	16 306	16 927
254	Fingolimod	−1902	−0.471	−0.0080	−2310	−2384
256	Rivaroxaban	−2496	−1.247	−0.0192	−3472	−3606
260	Botulinum	1690	−0.033	0.0000	1814	1868
261	Rivaroxoban	1541	0.143	0.0029	1662	1705
265	Denosumab	9661	1.406	0.0254	10 841	11 147
266	Mannitol	−412	−0.095	−0.0015	−506	−524
267	Ivabradine	1008	−0.096	−0.0008	935	949
275	Apixaban	62 745	−8.456	−0.0866	56 624	57 477
283	Ranibizumab	1308	−0.204	−0.0025	1167	1186
287	Rivaroxoban	268	0.052	0.0012	206	202
288	Dapagliflozin	39 436	3.971	0.0789	42 821	43 918
292	Aripriprazole	1	0.000	0.0000	1	1
297	Ocriplasmin	−50	−0.013	−0.0002	−67	−70
303	Teriflunomide	7667	0.819	0.0156	8287	8503
306	Pixantrone	−277	−0.035	−0.0006	−336	−348
312	Alemtuzumab	9435	0.575	0.0125	9784	10 018
315	Canagliflozin	48 668	3.315	0.0750	51 689	52 922
318	Lubiprostone	60	0.007	0.0001	66	68
320	Dimethyl fumarate	−10 919	−1.761	−0.0313	−12 367	−12 721
322	Lenalidomide	−129	−0.046	−0.0007	−165	−171
325	Nalmefene	5880	1.350	0.0237	6447	6598
326	Imatinib	−58	−0.029	−0.0004	−87	−91

Note. Reductions in SII and RII are reported so that positive values indicate a more equal distribution; positive values of "Population NHB" indicate that the intervention improves average health. Inequality aversion parameters of 10.95 and 0.15 are used to calculate the Atkinson and Kolm EDEs.
EDE indicates equally distributed equivalent; RII, relative index of inequality; SII, slope index of inequality; TA, technology appraisal.

from the base case, but the number of interventions that increases inequality rises from 5 to 12. When the ICER increase is attributed to lower QALYs, again the number that are health increasing is unaffected, but the number that increase health inequality rises from 5 to 8.

A movement from low (Atkinson ε = 0) to high (Atkinson ε = 20) inequality aversion altered the ranking of 9 of the interventions (see Figure A5 in the supplemental materials found at https://doi.org/10.1016/j.jval.2019.03.006). The ranking of interventions with pro-poor disease gradients such as hepatitis C (252) increased, whereas diseases with no gradient, such as atrial fibrillation (275 249), are demoted.

The joint impact of the cost-effectiveness threshold and inequality aversion parameter is shown in Figure 3. The cumulative social welfare impact of the 27 interventions becomes positive between threshold values of £5000 and £6000. At a threshold of £20 000, the change in population EDE ranges from 252 000 QALYs for ε = 0 and 278 000 for ε = 20. When there are higher opportunity costs, more health is lost is in the poorest groups, reducing any equity benefits.

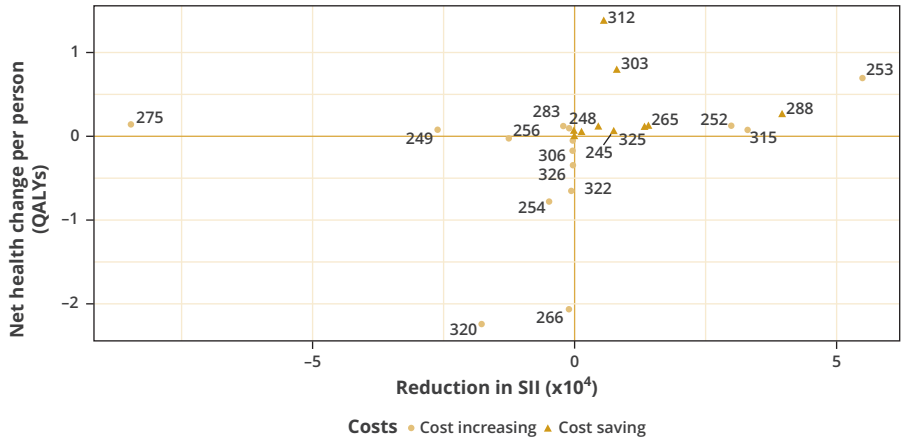
Discussion

Principal Findings

This study proposes a method to quantitatively analyze the potential health inequality impacts of new health technologies, with an application to 27 interventions recommended by NICE for use in England. Although the distribution of healthcare utilization determined the direction of the equity impact, the magnitude of the impact was largely driven by per patient net health benefits and the size of the patient population. TA 275 (apixaban), for example, had the largest negative equity impact and a patient population of over 450 000, whereas TA 253 (boceprevir) had the biggest positive impact and high net health benefits of 1.35 QALYs per patient.

Five interventions in our sample involved a tradeoff between health inequality and health improvement. Nevertheless, when these effects are combined using the Atkinson and Kolm social welfare indices, a positive change in EDE was still observed for these interventions, indicating that the increases in health

Figure 2. Equity impact plane showing the change in net quality-adjusted life years (QALYs) generated by a treatment and the impact on lifetime health inequality, as measured by the slope index of inequality (SII).



inequality are compensated for by the total health improvements. Our results, therefore, do not conflict with recommendations made from the standard CEA at the level of inequality aversion used in our base case analysis.

Although the data on NICE STAs are systematically extracted from published documentation, our results do not constitute a comprehensive health inequality impact analysis of NICE decisions over the time period. The assumption that treatments will fully replace all comparators is optimistic in calculating population net benefit and is not anticipated during the STA process. Using the incremental costs and QALYs cited by the manufacturer is similarly optimistic because we expect them to be biased toward the new treatment. When the manufacturer estimates were adjusted to reflect the average difference in cost-effectiveness with the ERG analyses, the population health impacts duly reduced, although the number of interventions involving tradeoffs changed only marginally.

Limitations

One limitation of our analysis is that we only used data on disease-specific utilization to calculate health benefit distributions and did not include other factors potentially influencing social differences in net benefit—in particular, technology-specific differences in utilization and health benefits. Our analysis assumed, for example, that all patients in need of treatment would receive the new technology and that the probability of uptake was not higher among socially advantaged patients who may be better able to navigate through complex administrative systems like the English NHS to secure access to the best available new treatment.[16]

Using existing patterns of utilization may also be biased if a new technology is expected to change patterns of uptake across social groups. If provision of a new treatment is likely to increase uptake in the most disadvantaged groups (as was argued in the case of recent hepatitis C treatments[17]), then current utilization would underestimate the benefits to health inequality. Nevertheless, if data on expected uptake patterns are available, they can be used to adjust or replace the healthcare utilization distributions used to allocate health benefits.

We also assumed that the incremental QALY gain of an intervention was the same across all groups. If it is believed that the incremental QALY gain would be higher in less deprived groups, for example if they were to adhere better to treatment or have greater capacity to benefit owing to fewer comorbid conditions, we may be overestimating inequality reductions. The "full" DCEA approach can account for these additional sources of inequality and can be recommended in instances where an intervention is expected to change patterns of utilization or when the direct health benefits to recipients of an intervention are expected to differ between socioeconomic groups. Nevertheless, the aggregate approach may still be informative in instances where there are strict time and resource constraints, particularly because committee members are used to adjusting estimates of cost-effectiveness to account for factors outside of the formal cost-effectiveness analysis, such as additional benefits not accounted for in the QALY. This simplified approach can therefore be seen as providing a useful ballpark quantitative estimate as a starting point for deliberation, on which committee members can then consider whether the impacts might differ markedly in practice in the context of the specific technology in question.

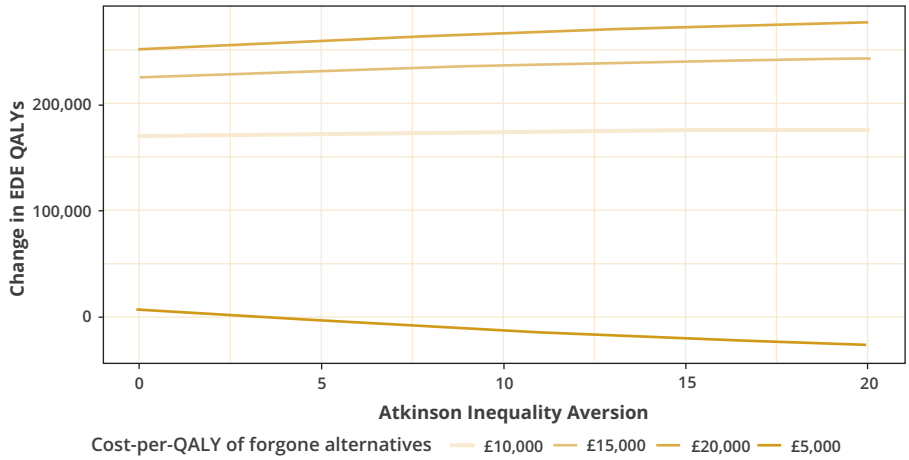
A number of intervention comparators are not included in the manufacturer's submissions, despite the costing template indicating their usage in clinical practice. For example, the costing templates for TAs 249 and 256 suggest that nearly 1.4 million patients receive either no treatment or aspirin for atrial fibrillation. Because the incremental benefits of switching patients on these regimens to the new treatments (dabigatran etexilate or rivaroxaban) were not captured, they were not factored in to our analysis.

Table 3. Health and health inequality impacts of the 27 technologies for each sensitivity analysis.

Health/inequality impact	Manufacturer estimates	ERG-adjusted costs	ERG-adjusted QALYs
Increase health, reduce inequality	14	6	10
Increase health, increase inequality	5	5	4
Reduce health, reduce inequality	0	1	1
Reduce health, increase inequality	8	15	12

ERG indicates evidence review group; QALYs, quality-adjusted life years.

Figure 3. Effect of the cost-effectiveness threshold and inequality aversion parameter on the cumulative net health impact of 27 health technologies.



EDE indicates equally distributed equivalent; QALY, quality-adjusted life year.

Another feature of our sample was the lack of recommended oncology-related interventions, with only 2 out of 27 for cancer patients. This may be due to the operation of the Cancer Drugs Fund (CDF) over this period. How this affects the results of this post hoc review is uncertain because the gradient of any net health benefits depends on the type of cancer. Incidence ranges from highly pro-poor for laryngeal and lung cancer, to pro-rich for the likes of breast cancer and malignant melanoma.[18] Nevertheless, our approach could be easily conducted within the appraisal process by manufacturers or ERGs using the otherwise confidential estimates of incremental health and costs. Similarly, output from probabilistic sensitivity analyses can be incorporated into the framework to quantify the uncertainty around inequality impacts.

HES may not be an appropriate proxy for distributing the expected benefits of a new technology for some diseases. For conditions such as alcohol dependence or diabetes, the majority of activity will take place in primary care, whereas mental health treatment primarily takes place in specialist centers not included in HES. If the socioeconomic distribution of activity recorded in these settings was systematically different from that seen in hospitals, then the net distributional effect estimated here will be inaccurate. For this review we selected a single data source that could be applied to all interventions, and we expect secondary care utilization to provide appropriate proxy social distributions. In future applications evaluating one indication at a time, access to the best source given the particular context should be sought.

The mapping of ICD codes to some of the disease areas is also inexact. An example of this is for the STAs 252 and 253 for hepatitis C patients. The most appropriate 3-digit ICD code for this disease is B18, which counts all chronic hepatitis patients, including hepatitis B, and may therefore distort the socioeconomic pattern used to allocate health benefits. Therefore, when using ICD codes to map to disease, future applications of our framework to individual interventions should consider the most appropriate tier of ICD code.

Last, we did not account for parameter uncertainty in our analysis. Estimates of uncertainty around incremental costs and QALYs were not systematically available, nor for the proportion of health opportunity costs accruing to each group. We could not therefore reflect uncertainty in our results through probabilistic sensitivity analysis, which would estimate the probability that each technology falls in a particular quadrant on the impact plane.

Conclusions

Our analysis presents a novel and straightforward way of estimating the health inequality impacts of health technologies that can be applied in routine practice. This aggregate approach demonstrates the potential utility of the DCEA framework in aiding decisions to allocate funding to new treatments.

The approach we propose is highly flexible and can be applied to any intervention that can be mapped to an ICD code, spanning a wide range of disease types. Where routine administrative data are available, it requires little additional resource and can model inequalities by any recorded socioeconomic characteristic. It is similarly flexible to evaluating inequalities with respect to additional characteristics such as ethnicity and age.[19]

Future work can also identify the most appropriate data sources for each disease area. Depending on the intervention, datasets that may better represent patients for diseases treated mostly in primary care or mental health facilities could be used to estimate the expected social distribution of benefits. Where possible, probabilistic sensitivity analysis can incorporate the combined uncertainty from all of the core inputs to characterize the uncertainty around the decision to fund an intervention.

Quantifying the distributional impact of new technologies, despite the importance of health inequality to policy makers and the general public, has not been undertaken in health technology assessment. This study and the proposed method can help to rectify this omission from the decision-making process.

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Supplemental Materials

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