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What is the cost of delivering routine vaccinations at GP practices in England? A comparative time-driven activity-based costing analysis

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ABSTRACT

Background: The expansion of available vaccines in recent years has increased the overall costs of the vaccine program and put pressure on providers responsible for vaccination. In England in 2016–17, GP practices responsible for vaccinating their local population were paid £227 million. However, the costs to general practice of delivering the program and the factors influencing these costs are unknown. Therefore, the aim of this study was to evaluate the costs of delivering the routine vaccination program at GP practices in England, to identify organizational factors impacting costs, and to compare these to the funding received.

Methods: Time Driven Activity Based Costing was undertaken at a convenience sample of nine geographically and socio-economically diverse GP practices in 2017–2018. Cost data were gathered for the preceding year using a survey and clinical and administrative staff kept activity logs for a 2-week period.

Results: The mean cost of delivering a childhood vaccination appointment was £18.20 (range £9.71-£25.97) and an adult appointment cost £14.05 (range £7.59-£20.88), of which 75% was for staff, 24% for facility costs and 1% for consumables. Organizational factors contributing to lower costs include: shorter length of allocated appointment; greater use of administrative and reception staff; lower working time for practice manager and practice nurse; and use of health-care assistants for adult vaccinations. The costs identified are lower than payments at all practices.

Conclusions: Funding received for vaccination activities was higher than costs at included practices. Several organizational factors have been identified that impact on program delivery costs that could be modified.

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Introduction

Vaccination against infectious diseases is an extremely cost-effective intervention,[1] however, with the rapid expansion of available vaccines in recent years,[2,3] the costs to governments and other payers for both vaccines, and the associated delivery programs have been increasing as recommended schedules have become increasingly complex. In England in 1990 the routine vaccine schedule consisted of eight vaccinations events for immunisation against eight infectious diseases, all targeted at children or adolescents.[4] The current schedule involves 16 shots for children against 11 diseases, with a further three in adolescents and four in adults (against influenza, pneumococcal disease and shingles in older adults and pertussis in pregnant women).[5] All routine vaccinations in England are provided free-of-charge to patients.

After nearly a decade of steady increases vaccination coverage in England has started to decline, with multi-year reductions observed in several important childhood vaccines, including measles, mumps, and rubella (MMR) and diphtheria, tetanus, pertussis and polio (DTaP/IPV) vaccines.[6] These reductions in coverage are particularly important in the context of the substantial measles outbreak currently affecting many European countries, including England.[7,8] In addition, the national averages do not reflect the significant and persistent regional variation, where coverage both in London and other large urban centers is significantly lower than other parts of the country (for example, in 2017 DTaP-IPV-Hib 12 months: England 93.4%, London 88.8%; MMR2 5 years: England 87.6%, London 79.5%), which exists alongside lower coverage in certain ethnic groups and in areas of higher deprivation.[9,10] For older adults, pneumococcal polysaccharide vaccine was introduced in 2003 and mean coverage in 2018 was 69.5%, but with significant geographic variation, ranging from 48.2% in the London Borough of Kensington and Chelsea to 78.1% in Knowsley (North West region.)[11] Vaccination against shingles was introduced in 2013 and cumulative mean coverage remains low at 41.0%[12]

Funding

In England, GP practices are independent private organizations that are contracted to provide health services to a defined population through a nationally negotiated contract (the General or

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Personal Medical Services contract) by NHS England (NHSE), the body responsible for commissioning primary health-care services.[13,14] Currently payments made to practices providing vaccinations are not based on the costs of delivering vaccination services, but instead on achieving outcomes defined within this contract. Firstly, practices receive a 'global sum' capitation payment that is not related to activity, designed to fund 'structural costs' for all services provided by the practice based on size.[15] If practices opt out of providing childhood vaccinations they receive a deduction of 1–2% of this payment. Secondly, delivery of some vaccines incurs an item-of-service payment, while others are considered in groups and payment is received on completion of a course, or when specified levels of coverage are achieved as shown in Supplementary material 1 – Table 1.[16] There is also an additional payment for timely vaccination when children receive vaccines during the first 3 months of eligibility. Finally, a small number are incentivized through the Quality Outcomes Framework (QOF), a pay-for-performance scheme (primarily influenza vaccine in clinical risk groups).[17]

These contracting arrangements are subject to annual negotiations between the Department of Health and Social Care (DHSC), NHSE and the General Practitioners Committee of the British Medical Association.[18] The threshold targets have remained the same since the contract was introduced in 2004; however, the fee-for-service payment has been incrementally increasing over time, from £7.64 in 2013 to £10.06 in 2018, a 32% increase in 5 years, which has increased the costs to the government of delivering the program. In 2016–2017 NHSE paid GP practices £227 million for activity related to vaccination (excluding QOF payments and global sum payment).[19]

However, the system lacks transparency due to its complexity, and payments to practices are not aligned with costs. There are very few studies evaluating the costs to practices associated with delivering vaccinations to determine the appropriateness of payment levels. Together, these factors make it extremely challenging to recommend changes to the funding system that may improve coverage. Therefore, the aim of this study is to describe and evaluate the costs of delivering the routine vaccination program at GP practices in England and to compare them with funding payments and identify factors associated with differential costs between practices.

Results

Following circulation of the study details, 14 practices retuned expressions of interest. We excluded four practices as they were geographically similar to already included practices, and one did not complete data collection. Therefore, between May 2017 and February 2018, 9 practices completed the data collection activities. Data collection commenced at the time of recruitment. No practices collected data during the initiation of the seasonal influenza campaign (September–October 2018). Their characteristics are presented in Supplementary Material 2 – Table 2. Detailed information on each practice is available in the precursor study.[20]

Costing

The costs of delivering a single vaccination appointment during the 2-week study period at each practice are presented in Supplementary Material 3 – Table 3, alongside the number and mean length of appointments at the practices.

The mean cost for a childhood appointment was £18.20 (95% CI £14.26-£22.15) and ranged from £9.71 at practice D to £25.97 at practice A. Of the cost, 74.3% (£13.52) of the mean total was staff costs and 24.4% (£4.44) facility and 1.4% (£0.25) vaccination specific. Of the staff costs, 54.7% (£7.40) was clinical and 45.3% (£6.12) administrative, of which 36.3% (£2.22) was attributed to clinical staff and 63.7% (£3.90) to administrative staff.

The mean cost for an adult appointment was £14.05 (95% CI £11.03-£17.08) and ranged from £7.59 (H) to £20.88 (C). The contributing costs were similar to those of childhood appointments with 75.9% (£10.66) from staff, 23.4% (£3.29) from facility, and 0.7% (£0.10) from specific. Of the staff costs, a lower proportion was from clinical staff (41.2%, £4.40) due to the shorter appointment times and thus a higher proportion was from administration costs (58.8%, £6.26). A similar proportion of the admin time was attributed to clinical staff (36.2%, £2.27) and admin staff (63.8%, £4.00) as for childhood appointments.

To preserve the anonymity of practices, the facility costs are not being published separately; however, the overall annual facility costs per registered patient ranged from £9.88 to £50.02 with a mean across the practices of £28.67 (95% CI £20.86-£36.48). These costs are fixed and unchanged by the vaccination program.

Vaccination specific costs

Most practice managers were not able to disaggregate the consumables used in vaccination from their general orders for the practice. However, two practices provided detailed information on the cost of consumables (e.g. needles, syringes) and detailed usage during appointments (D & J), which ranged from £0.19 – £0.24 per childhood appointment and <£0.10 for adult appointments with a single injection. Practice managers were not able to disaggregate the costs of providing and maintaining cold-chain (e.g. utilities and fridges) from the overall facility costs and so these have not been reported separately. Therefore, a nominal cost of £0.25 and £0.10 for consumables was added to each childhood and adult vaccination appointment, respectively. Although it is possible there is some variation of consumables used by practice, it is not likely that this would be significant enough to greatly affect overall appointment costs.

Cost per childhood vaccine

Part of practices' remuneration for vaccinations is a fee-for-service payment per vaccine. Thus, another way of considering the costs is per vaccine delivered, rather than per appointment. Childhood appointments vary in length, cost and the number of vaccinations delivered (Supplementary Material 4 – Table 4).

The appointments with the largest number of vaccinations (8-week and 12-month) gave the lowest cost per vaccine (£5.19 and £4.72, respectively), despite having the longest appointment lengths. Currently, the fee-for-service payments are not related to the costs at practice level as these were previously not known. The costs borne by the practice range from £4.72 to £9.55 per vaccine. Fee-for-service payments for individual childhood vaccines (Table 1) range from £4.90 for rotavirus to £10.06 for meningococcal group B, suggesting that payments to practices exceed costs in this context.

Sensitivity analysis

The main area of the TDABC model with greatest uncertainty is the weighting of appointment resource use in calculating the FCCR. Sensitivity analysis around alternative weightings are presented in Supplementary Material 5 – Table 5, which shows that if GPs were allocated 4 times the resources of nurses, vaccination appointment costs reduced by 4.5%. If GP appointments and nursing appointments are weighted equally, this increases vaccination appointment costs by almost 25%.

Factors affecting costs

The underlying facility cost base of the practice made a moderate difference to the overall totals, with contributions ranging from 31.7% of the total childhood appointment cost at practice J to 10.3% at D. However, these costs are largely fixed and related to the underlying business structure and locally negotiated contracts for premises and services, which are outside the scope of this study.

The cost of staffing is the main variable cost, which is dependent on three factors: task allocation, time spent and salary costs. At the request of the practices we have not published reported salary costs; however, the relative salary cost at each of the practices is presented in Supplementary Material 6 – Table 6. It was not possible to include the data for administrators and receptionists due to the wide range in job specifications and salary scales.

For childhood appointments, the lowest total clinical staff cost was at practice D (£4.67), which was primarily due to the low salary cost with an average appointment length (13.9 min). Practice F had similarly low costs (£4.88); however, this was due to very short appointments (9.8 min), despite having higher than average clinical staff costs. This was achieved by their system of a dedicated baby clinic with two PNs and two HCAs with 5 min-allocated appointments. The highest clinical cost (£10.86) was found in practice C that had the longest appointment length (22 min) and slightly higher than average staff costs. Practice G had high costs (£10.14) primarily due to higher staff salaries in London, despite an average appointment length (18.3 min). For adults, Practice E had the lowest clinical cost due to the very short appointment length (6.8 min) and low salary costs. Despite having both average salary costs and average appointment length (9.1 min), practice H had very low clinical costs (£2.92) due to the high use of HCAs.

The total administration costs generally fell within a relatively narrow range. The highest cost was found in practices A (£8.83-£9.01) and C (£8.63). Practice A had the smallest list size with a small management team, so the practice manager had a much larger role in data collection and submission than elsewhere. Practice C had a relatively high contribution from the practice nurse (£4.22, 48.9% admin cost), particularly relating to data collection, submission, and vaccine ordering. Both the London practices (G and J) had relatively high costs from admin staff (£5.19, 79.8%; £5.84, 80.7%, respectively) as they had specialist administrative staff to undertake the associated workload.

The lowest total admin cost was found in practices H and D. Practice H had the lowest staff admin costs overall (£2.26), despite relatively average staff salaries. This is due to the very low cost of clinical admin time (£0.86) as much of the data entry is undertaking during the baby clinic by one of the HCAs. The practice also employs a specialist administrator who undertakes most of the reminder, recall, ordering and data entry, with little involvement from the PM or PN.

Effect of delivery model on cost

Supplementary Material 7 – Table 7 shows the relative cost of each of the staffing components as compared to the mean cost using standardized salaries, which removes the effect of differential salary costs in different geographic regions. This demonstrates that the delivery systems in place at the smaller practices (A, B & C) are relatively costly. Smaller practices are less likely to have administrators or specialist receptionists to undertake the administrative workload, so instead this is completed by the PN and PM, who have higher salaries. Practice C is the most costly overall due to a combination of long appointment times and a large role for both the PN and PM in administration. In the case of practice B, the PN has the highest administration cost, being almost double the mean (1.97). These three smaller practices achieve high levels of vaccine coverage alongside their high costs.

The lowest cost system is in practice H, which is around 40% lower than the mean for both childhood and adult appointments. For childhood appointments, the clinical cost is close to the mean (0.8), despite the shortest appointment time (9.0 min) as there are two staves contributing to the cost of each appointment, with the HCA undertaking preparation and data entry alongside the nurse. This reduces the amount of administration undertaken by PNs and the rest is undertaken by a specialist administrator with a relatively lower cost than the PM. Practice H also had the highest number of adult vaccinations given by an HCA (60% of the total), which meant that despite an average appointment length (9.1 min), the relatively clinical cost was the lowest (0.72).

Practice F also had relatively lower costs for childhood appointments, partly due to the short appointment length (9.8 min), reducing the clinical cost to 60% of the mean, and with a relatively low administrative cost (0.59) by using an administrator. This practice has relatively good coverage of childhood vaccinations, but low coverage of adult vaccinations. Practice D had the lowest administrative cost due to the large role for receptionists in both reminder/recall activities and data submission. Despite the relatively long appointment times for adults in practice G (13.3 min), the cost was very close to the mean (0.99) as 55% of these vaccinations were given by an HCA during the study period.

Comparison with payments

Annual payments to the GP practices included in this study were extracted from data from 2016 to 17 and are presented in Supplementary Material 8 – Table 8 for each funding stream.[19] These payments integrate some activity that is not included in this study (e.g. seasonal influenza), which creates a challenge in making a direct comparison. However, estimated costs have been compared to payments for total 1. childhood, 3. rotavirus and shingles, and 4. meningitis vaccination programs, excluding 2. influenza and pneumococcal payments, which are reported together. The costs associated with program delivery are lower than payments in all cases, meaning that overall it is likely that payments are likely to meet the costs associated with delivering the program.

Discussion

The purpose of this study was to calculate the costs associated with delivering the routine vaccination program at GP practices to identify factors impacting on costs and to compare this to payments practices receive. Overall, the estimated operational costs and payments at practice level suggest that payments cover costs. Excluding cost variations outside an individual practice's purview (e.g. higher salary costs in London), organisational factors that may contribute to lower costs include: shorter allocated appointment length; greater use of administrative and reception staff; less time spent by higher salaried staff (such as the practice manager and practice nurse) for administration; and use of HCAs for adult vaccinations. However, each of these factors needs to be considered in the context of total GP practice service delivery, which is outside the scope of this study, especially as there is currently no evidence for any association between cost and coverage. Although this should be subject to further investigation.

After standardizing for salary differentials, the larger practices in this sample had lower costs overall, due to higher use of relatively less expensive administrators, receptionists, and HCAs for administrative tasks. However, these practices also had lower coverage overall, particularly the two large practices in London, where coverage if childhood vaccinations is known to be lower than other areas of England.[6,9,10] Due to the level of data collected from within a busy general practice, the sample size was small. This means that the absolute costs are unlikely to be generalizable to General Practices in England more widely. The small sample size also precludes regression analysis to evaluate the statistical significance of any association with cost and coverage and these factors should be evaluated on a larger sample. However, the underlying factors identified here (such as time spent, appointment length and task allocation) are likely to be associated with cost levels more widely. From the results presented here, we have concluded that overall funding is likely to meet costs, this may not be true for each component of the program. This is particularly important as the cost of delivering each appointment varied across the practices 2.5-fold. It is also not clear in the contracting documentation how much of the underlying facility costs is expected to be covered by the 'global sum' capitation payment provided by NHSE to practices, which is important as facility costs comprise around a third of the overall childhood appointment cost for four of the practices included here (A, E, F & J).

Cost comparison

To our knowledge no other studies have evaluated the costs of delivering non-influenza routine adult vaccination appointments; however, several studies have examined childhood vaccination costs. One recent study conducted in England used time-and-motion methods to record time per activity within a childhood vaccination appointment.[23] This reported a mean appointment time of 9.5 min (95% CI 7.7–11.3), with an additional 10.1 min of non-observed pre-appointment preparation. This was similar to the time we observed in practices F and H. The total cost described was £11.90, which did not include any facility costs. The equivalent mean cost of staff and specific costs in our study is £13.77. Much of the administrative activity involved in vaccination was not measured and instead times was allocated following an interview with a nurse, but did not involve any administrative or management staff. No information was provided on the task allocation or activities undertaken at each practice. A previous study conducted in New Zealand in 2009, which used ABC to analyse the vaccination delivery system at 24 practices, found a mean cost per appointment of NZ$25.89 (range NZ$14.38–32.50), which equates to £15.08 (range £8.38-£18.93) when adjusted for inflation (to 2018) and converted to British pounds.[24,25]

Task shifting

One of the ways of modifying the cost base of delivering the program is to shift tasks between staff groups. The most widely studied form of task shifting in primary care is from doctors to nurses, where the evidence suggests that it can reduce costs and improve preventive outcomes, but may also result in increased number of return visits and longer consultations.[26–28] Within the context of this study, two types of task-shifting may reduce costs when delivering the vaccination program. The first is to shift some vaccination activity from nurses to healthcare support workers (including HCAs), who are able to give influenza, pneumococcal and shingles vaccines to adults within a GP practice setting. For each vaccination, they have to receive a Patient-Specific Directive signed by a prescriber before the vaccine can be given.[29] HCAs were only used at three practices included in this study (B, G, and H). Given the low levels of coverage of adult vaccines at some of the practice included here, greater used of HCAs may be a mechanism to achieve higher coverage, although this remains an un-studied area. It could also reduce overall practice time spent on vaccination as HCA appointments were much shorter than most nursing appointments at the practices studied here.

The second type is to shift administrative activity from nursing staff to administrative staff. Practices B, E, and F all had high proportions of time spent on non-clinical tasks by the PN (~55%), with higher associated costs, which was mainly ordering and stocking vaccines. This had been shifted to HCAs or administrators in several other practices, including practice H which had one of the lowest cost systems alongside a low proportion of nursing time spent on admin. Practice G had shifted administrative activity from nurses to administrative staff and had the lowest overall cost for admin activities from the practice nurse, but relatively high costs for admin costs overall. Further work needs to be done in this area to evaluate the relative costs and benefits for making recommendations on how task shifting could improve program delivery.

Policy recommendations

At a local level, knowing the specific costs incurred by practices can then enable practice management to identify funds available for vaccination that can be used to provide additional services in areas of low coverage and may act as an incentive to increase volume of existing services where these are revenue generating. This information can also be used at high-cost practices to reduce costs overall and use the additional funds improve service delivery quality, including improved administrative efficiency (e.g. implementation of new electronic systems) to free up staff time for other activities. At national level the rationale for the amounts agreed during GP contract negotiations is not made public; however, knowledge of overall costs and factors associated with lower costs can be used to determine adequate funding levels and identify available funds for use within the system to improve coverage, particularly in London and other urban areas, and to reduce inequalities. Therefore, we recommend:

- Costing should be undertaken at a wider range of practices to confirm amounts and associations identified here.
- Accurate cost data should be used at national level to determine appropriate funding levels for the program and identify funds that can be used to provide additional services to improve coverage and reduce inequalities.
- Where funding is higher than costs, practices should be supported in using available funds to provide additional cost-effective services in areas of lower coverage and improve administrative efficiency to free up staff time for other activities.

Limitations

This is a small, convenience sample of practices, which are unlikely to be representative of all GP practices. No very small or very large practices were included. The methods rely on self-reporting of activities, which may be subject to reporting bias. Activity logs were kept during different weeks at each practice and activity is not even throughout the year. The small sample size precluded statistical analysis of practice characteristics with costs. This study only considers costs to the GP practice and not to patients or society.

Conclusions

It is likely that funding covers costs associated with vaccine program delivery at GP practices. However, this need confirming on a larger sample of practices. Organizational factors that could be modified to reduce costs, including reducing allocated appointment length; greater use of administrative and reception staff; reduction in working time for the practice manager and practice nurse for administration; and use of HCAs for adult vaccinations. While it is not known if this improves coverage, knowledge of costs and associated factors can be used to identify potential cost savings within the program to improve efficiency and allocate available funds to additional activities to improve coverage and reduce inequalities.

Methods

The purpose of the study methods is to quantify all the costs incurred by the practice, including facility operating costs, staffing, and consumables and allocate these to the activity associated with delivering vaccinations during the 2-week study period.

Sampling

The sampling method and characteristics of included practices are described in detail in the associated paper.[20] We recruited a sample of nine geographically and demographically diverse practices via the National Institute for Health Research Clinical Research Network of more than 2,000 GP practices signed up to a scheme of payment for participating in research projects. We aimed to recruit a non-representative convenience sample of 10 practices (due to our available capacity) from a range of geographic and socio-economic contexts. A £350 shopping voucher (£500 in London) was provided to participating practices.

Consent and ethical approval

We gained written, informed consent from each participant prior to commencing data collection. The study received ethical approval from the London School of Hygiene and Tropical Medicine Ethics Committee and the NHS Health Research Authority (project ID 212278).

Time-driven activity-based costing

Costing routine vaccine program delivery has previously been undertaken in New Zealand using Activity Based Costing (ABC) methods,[25,30] which allocate costs to complex processes within organizations to identify underlying cost drivers.[31] More recently, ABC has been updated to reduce the administrative burden of data collection and is now termed Time-Driven Activity-Based Costing (TDABC).[32–34] This method has been applied to evaluate the costs of complex health service delivery in both primary and secondary care.[34]

TDABC involves a 7-step process for identifying and allocating costs.[35] The results of steps 1–4 are presented in a precursor paper using the same sample.[20] In summary, the condition under analysis is defined as a patient registered at a GP practice who is eligible for routine vaccination. Seasonal vaccines (including influenza), other non-routine vaccines (e.g. for travel) and any vaccinations not given at GP practices are excluded. The Care Delivery Value Chain (CDVC; a visual representation of the main activities involved in providing vaccination) and a detailed process map have been developed in the linked paper.[20]

This study focusses on the results of steps 5–7. In step 5, data are generated on all vaccination-related activity undertaken in the 2-week study period and all costs incurred by the practice in the preceding 12 months.

Activities

Activity logs were provided to all staff involved in vaccination at each practice who then recorded all time spent on vaccination specific activities over a 2-week period, which were extracted and uploaded into Microsoft Excel for analysis. The included activities are presented in Supplementary material 9 – appendix 1. Vaccination appointments were grouped into childhood appointments or adult appointments and mean length by practice calculated, as well as the mean between practices.

Costs

To produce cost data, the practice manager completed a detailed survey, the components of which are presented in Supplementary material 9 – appendix 2. All costs incurred by the practice in the preceding complete financial year (April 2016 to March 2017) were included, but no data were collected on costs incurred outside the practice or by patients.[36] The costs captured were divided into facility costs (fixed: e.g. rent, utilities), staff costs, and vaccination specific costs (e.g. consumables). The costs of the vaccines are not included as these are paid for by Public Health England (PHE) and not borne by the practice or NHSE.

Steps 6 and 7 involve dividing and allocating the costs to the vaccination activity during the study period. Firstly, we calculated Capacity Cost Rates (CCR), defined as cost per minute of available time. The Facility Capacity Cost Rate (FCCR) was calculated by dividing the total annual facility cost by the total annual appointment time delivered by the practice (including vaccination and non-vaccination) . This was then weighted by staff group (health-care assistant (HCA), PN, GP) to account for differentials in resource use. A nursing appointment was allocated a weighting of 1, a GP appointment a weighting of 3 and an HCA appointment of 0.5, based on approximate salary differentials (HCA £16,000:PN £32,000:GP £92,500).[37,38] This weighted cost per minute of activity was then multiplied by appointment length (minutes) to give a cost per appointment. The Staff Capacity Cost Rate (SCCR) was calculated by dividing annual salary and all on-costs (i.e. employer national insurance and pension contributions), by the total number of available working minutes per year. Where salaries were provided without on-costs, these were estimated by the addition of 25% to the salary figures provided, based on advice from two PMs who participated in the study.

For clinical time the SCCR was calculated for each staff group based on 45 weeks worked each year, 2,250 min per week (37.5 h, full time) and then allocated to each appointment by length. For staff admin time not attached to a specific appointment (e.g. data uploading), the total amount of time was proportionally allocated to each appointment based on the number of appointments during the study period. To calculate the vaccination specific costs, information about the consumables used per appointment were recorded in the staff activity logs, and practice-level costs (e.g. fridges) were recorded in the practice manager's survey and allocated proportionally to each appointment. Therefore, the cost of a vaccination appointment of Z minutes is calculated as follows: (Z x FCCR) + (Z x SCCR) + (specific costs per appointment). Costs were calculated for mean appointment time spent for adult and childhood appointments at each practice, as well as an overall mean cost between all practices.

Sensitivity analysis

The greatest area of uncertainty in the cost model is the weighting of facility costs by staff group resource use, as little is known about differential resource use by GP practice staff. We calculated the FCCR by dividing facility costs between all the appointments delivered by the practice per year. and then weighting based on resource use, with a GP appointment being allocated 3 times the facility costs compared to a nursing appointment. However, other ways of weighting resource use by appointments, so two alternatives were evaluated: firstly, if GP appointments had even higher resources use (4 times a nursing appointment) and secondly, if GP appointments and nursing appointments had the same resource use.

Standardization by salary

GP practices are free to negotiate staff salaries directly, which creates variation in the amount staff are paid across the included practices, which is not related to program delivery. To isolate the effect of different delivery models we standardized staff group salary costs, by calculating the mean salary for each staff group (e.g. nurses, practice managers) and put into the model in place of actual salaries. To compare standardised costs between the practices using mean salaries, the mean cost for each component of the staff costs (clinical, administrative) was then calculated and given a value of 1 and relative costs calculated as a proportion of the mean and presented in Supplementary Material 7 – Table 7 (where a value less than 1 shows a lower cost system and a value greater than 1 a more costly system).

Comparison with payments to practices

To evaluate practice costs against funding, the payments made to the included practices for vaccinations in 2016–17 were extracted from routine data published by NHS Digital.[19] These are total annual payments made to individual GP practices by NHS England for activity and outcomes specified in the GMS contract, which includes payments for routine vaccination. We then estimated the total annual cost to each practice for delivering routine vaccinations by using activity data published by NHS England (the 2016–17 routine vaccine coverage data[6]) and multiplying the mean cost at each practice for a childhood and adult appointment calculated in this study by the total number of annual appointments reported in the coverage data. Timeliness data are not publicly available and given that being vaccinated on time is high (>90%) even in lower coverage areas,[39] for simplicity we assumed that all timeliness threshold payments were achieved.

Abbreviations

ABC	Activity Based Costing
AD	Administrator
CCR	Capacity Cost Rate
CDVC	Care Delivery Value Chain
DHSC	UK Government Department of Health and Social Care
FCCR	Facility Capacity Cost Rate
GP	General Practitioner
HCA	Healthcare Assistant
NHS	UK National Health Service
NHSE	National Health Service England
PM	Practice Manager
PN	Practice Nurse
R	Receptionist
QOF	Quality Outcomes Framework
SCCR	Staff Capacity Cost Rate
TDABC	Time Driven Activity Based Costing

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Contributions

TCB conceived the study with SMJ, MR and ME. TCB designed the Time Driven Activity Based Costing methods and conducted the data collection activities and analysis, and produced the initial draft of the manuscript. KM developed the model to estimate comparisons of costs to payments. All authors reviewed the manuscript and approve the final draft.

Disclosure of potential conflicts of interest

We declare that we have no conflicts of interest.

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