

# BMJ Open Time-driven activity-based costing for patients with multiple chronic conditions: a mixed-method study to cost care in a multidisciplinary and integrated care delivery centre at a university-affiliated tertiary teaching hospital in Stockholm, Sweden

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**To cite:** Keel G, Muhammad R, Savage C, *et al.* Time-driven activity-based costing for patients with multiple chronic conditions: a mixed-method study to cost care in a multidisciplinary and integrated care delivery centre at a university-affiliated tertiary teaching hospital in Stockholm, Sweden. *BMJ Open* 2020;**10**:e032573. doi:10.1136/bmjopen-2019-032573

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2019-032573>).

Received 25 June 2019  
Revised 29 January 2020  
Accepted 25 April 2020



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## ABSTRACT

**Objective** This study can be applied to cost the complex non-standardised processes used to treat patients with multiple chronic conditions.

**Design** A mixed-method approach to cost analysis, following a modified healthcare-specific version of the seven-step Time-Driven Activity-Based Costing (TDABC) approach.

**Setting** A multidisciplinary integrated and person-centred care delivery centre at a university-affiliated tertiary teaching hospital in Stockholm, Sweden, designed to improve care coordination for patients with multiple chronic conditions, specifically diabetes, cardiovascular disease and kidney disease.

**Participants** 314 patients (248 men and 66 women) fit inclusion criteria. Average age was 80 years.

**Results** This modified TDABC analysis costed outpatient care for patients with multiple chronic conditions. The approach accounted for the difficulty of conceptualising care cycles. The estimated total cost, stratified by resources, can be reviewed together with existing managerial accounting statements to inform management decisions regarding the multidisciplinary centre.

**Conclusions** This article demonstrates that the healthcare-specific seven-step approach to TDABC can be applied to cost care for patients with multiple chronic conditions, where pathways are not yet discernable. It became clear that there was a need for slight methodological adaptations for this particular patient group to make it possible to cost these pathways, stratified by activity and resource. The value of this approach can be discerned from the way management incorporated the results of this analysis into the development of their hospital strategy. In the absence of integrated data infrastructures that can link patients and resources across financial, clinical and process data sets, the scalability of this method will be difficult.

## Strengths and limitations of this study

- This was a cost analysis using the healthcare-specific seven-step Time-Driven Activity-Based Costing framework.
- Mixed methods allowed for comprehensive data set capture and thus more valid cost estimates.
- In the absence of care pathways, in-practice visit frequencies were used to characterise complex care.
- A lack of integrated data required substantial research hours for data processing.
- Regular and open communication with clinical and economic staff was required.

## INTRODUCTION

Patients with multiple chronic conditions are the largest consumers of hospital resources.<sup>1–3</sup> Hospital care consumes the largest proportion of healthcare spending in Organisation for Economic Co-operation and Development countries and the USA, accounting for 30% to 50% of national healthcare expenditure.<sup>4</sup> Costs continue to rise despite policy attempts to rein in hospital expenditures,<sup>5</sup> with efforts often focused on how third-party payers can better incentivise care providers.<sup>6</sup> Examples include priority setting, global budget negotiations, benchmarking, pay for performance, bundled payments and gate-keeping.<sup>7</sup> Providers struggle to deliver more efficient care, but often respond to these incentives with unpredictable and sometimes counterproductive behaviours.<sup>8</sup> At the same time, both clinical and administrative staff work within their various silos, and data and

information structures divide along the same lines.<sup>9</sup> The most sick and expensive patients, largely patients with multiple chronic conditions, require that care should be coordinated across these boundaries over the full cycle of care if costs and quality have to be effectively managed.<sup>10</sup>

Within recent years, bridging these boundaries when measuring both outcomes and cost has been recognised as a priority.<sup>10</sup> Value Based Health Care (VBHC) is a framework that encourages organisations and systems to align around the value equation, that is, maximise health outcomes generated for patients while decreasing the money spent. Providers are reimbursed for the costs of delivering care over the patient's entire cycle of care, crossing organisational boundaries.<sup>6</sup> However, deeply rooted fragmentation, combined with the disordered state of much of care delivery, challenges providers' attempts to incorporate this approach to costing.<sup>11</sup>

Diagnostic Related Grouping (DRG) reimbursement systems were established in the 1980s to encourage providers to reduce costs. Since then, national authorities have released cost-accounting principles that would better inform DRG-based reimbursement.<sup>12</sup> Providers continued to operate inefficiently, experiencing both early hospital discharges and a lack of accountability for complications and hospital readmissions.<sup>13</sup> DRGs did not reimburse over the entire care cycle and were not intended for managerial decision-making.

Activity-Based Costing (ABC) has been the most common costing approach to inform DRG reimbursement.<sup>12</sup> ABC is, however, resource intensive, difficult to update and applied inconsistently.<sup>14–16</sup> Time-Driven Activity-Based Costing (TDABC), an innovative version of ABC, has been reported to capture the cost of care processes more simply than ABC.<sup>17–19</sup> TDABC has been extensively described in the literature,<sup>10 14 15 20</sup> essentially as a process-based costing approach that uses two key parameters in costing activities: (1) the annual cost of resources used within processes and (2) the time each resource is used within process steps. TDABC has been recommended for use within the VBHC framework.<sup>10</sup> Within VBHC, bundled payments reimburse for the treatment of a specific condition over the entire care cycle, from first visit to follow-up, including complications and readmissions.<sup>10</sup> TDABC is recommended for use by both payers and providers, when faced with questions relating to the cost component of the value equation<sup>10</sup>. The healthcare-specific TDABC version consists of seven steps to generate cost estimates of care cycles for specific medical conditions.<sup>10</sup> This TDABC approach has been increasingly applied, and due to its simple logic and transparent depiction of care processes it has demonstrated the ability to accurately inform operational improvement and cost-saving decisions in hospitals.<sup>20</sup> TDABC has also been integrated into bundled payment reimbursement systems, but these have been mostly of non-chronic conditions with well-established care guidelines.<sup>20</sup> Such care processes present a high degree of standardisation with services provided in a sequential manner,<sup>21</sup> and

health systems still struggle in developing consistently effective bundled payments for more complex medical conditions.<sup>11</sup>

In the healthcare-specific TDABC approach, the treatment pathway is specified in the second step: define the 'Care Delivery Value Chain' (CDVC). The term CDVC originates from the VBHC literature<sup>10</sup> and is defined as a depiction of all activities performed when treating a condition from the beginning to the end of the care cycle.<sup>22</sup> The CDVC for chronic conditions should depict all activities performed over a specified time period, typically 1 year, including those associated with comorbidities.<sup>10 22</sup> For most patients with multiple chronic conditions, standardised treatment pathways or guidelines do not exist, and these patients often receive a large amount of poorly coordinated care spanning many components of a fragmented system.<sup>3 23</sup> As these patients' treatments are the most expensive,<sup>1–3</sup> cost monitoring is a priority. TDABC has not been applied to cost fragmented care, but has been used to cost complex non-linear pathways with multiple decision nodes, which is well demonstrated in the study by Morris *et al.*<sup>24</sup> When treating patients with multiple chronic conditions, complex care delivery can appear chaotic without discernable, coherent and connected healthcare interactions,<sup>25</sup> making it a challenge to specify decision nodes.

The VBHC literature provides a framework to cost care for patients with multiple chronic conditions using TDABC, but this is yet to be demonstrated in the published literature. This study aims to explore how TDABC can be applied to cost care for patients with multiple chronic conditions.

## METHODS

### Study design

This TDABC costing analysis used multiple methods for data collection and analysis to cost 2017 outpatient clinical care processes for patients with at least three chronic conditions: established diabetes, cardiovascular disease and kidney disease. The analysis was performed according to the seven-step approach to TDABC in healthcare<sup>10</sup> and insights from a review of TDABC applications in healthcare.<sup>20</sup>

### Study setting

This study was conducted at a multidisciplinary and integrated care delivery centre at a university-affiliated tertiary teaching hospital in Stockholm, Sweden.<sup>26</sup> The centre, established in 2013, is designed to coordinate integrated person-centred care for patients with cardiovascular disease, chronic kidney disease and diabetes and from which it derived its name—the HND Centre (heart, nephrology and diabetes). The HND care team consists of registered nurses (RNs), doctors and 'undersköterska' (USK)—equivalent to the American *Licensed Practical Nurse* or British NHS *Health Care Assistant*. While all HND care delivered in the hospital is

**Table 1** The seven steps of TDABC, and our approach to data collection and analysis

TDABC step	Data collection	Data analysis
1. Select the medical condition	► Project lead of the RCT provided the inclusion criteria for HND patients	► None required.
2. Define the CDVC	► Meeting with clinical staff ► Contextual observations ► Electronic medical records	► Identify activities present in delivery of outpatient care at HND. ► Extract frequencies of each activity type per patient from the QV and the scheduling system.
3. Develop care process maps	► Meeting with clinical staff ► Contextual observations	► Create a process maps of HND outpatient activities, that is, patient visit. ► Identify resources involved in each activity step. ► Validate process maps with staff.
4. Obtain time estimation for each activity	► Contextual observations	► Calculate the mean duration of use of each resource in each activity.
5. Estimate cost of resources	► Hospital accounting sheets ► BI firm accounting sheets	► Estimate the total annual cost of each resource.
6. Estimate CCRs of each resource	► Hospital HR sheets	► Estimate the practical capacity, and calculate the capacity cost rate of each resource.
7. Calculate the total cost of care	► Chart of accounts, DRG cost estimates and BI accounting sheets for validation purposes	► Calculate the total cost of each activity, and the total cost of outpatient care at the HND clinic, and reconcile against the hospital's financial information.

BI, Business Intelligence; CCRs, capacity cost rates; CDVC, care delivery value chain; DRG, Diagnostic Related Grouping; HND, heart, nephrology and diabetes; HR, human resource; QV, Qlikview; RCT, randomised control trial; TDABC, Time-Driven Activity-Based Costing.

coordinated by the HND team, only outpatient care is delivered at the Centre. A detailed description of the HND Centre is provided in the study by Spaak.<sup>27</sup> The HND Centre is a practical example of an Integrated Practice Unit (IPU)<sup>22</sup> for treating patients with multiple chronic conditions.

### Data collection and analysis

The methods for data collection and analysis are presented based on the seven TDABC steps and are described in table 1. Throughout this article, all costs were converted from SEK to euro at a rate of 10 to 1, because the conversion rate has fluctuated between 9.5 and 10.5 to 1 since 2017.

#### Step 1: select the medical condition

The medical condition selected was that presented by HND patients and can be summarised as established cardiovascular disease, diabetes mellitus type 1 or 2 and established kidney disease. Detailed inclusion and exclusion criteria have been defined by a group of clinical consultants for an ongoing randomised control trial (RCT) that aims to evaluate the clinical outcomes and experience for patients treated at the HND Centre.<sup>28</sup> Of note, 314 patients (248 men and 66 women) fit HND inclusion criteria and received treatment at the HND Centre in 2017. The average patient age was 80.

#### Step 2: define the CDVC

The CDVC was defined as activities performed over 1 year of care and was limited to care delivered at the HND Centre. The CDVC was described using annual frequencies of care delivery activities performed in practice, as opposed to a sequential process or standard.

A meeting was held with HND staff to list care delivery activities at the HND clinic. This list was corroborated through non-participatory contextual observations and when extracting HND visit frequencies from hospital systems.

The frequencies of activities were initially obtained through the Qlikview (QV) software package. QV data for HND patients were provided by the hospital's Production and Operations Analysis Department, who used QV software to extract data from a Stockholm municipal database containing patients' medical records. From the controller at the hospital, we learnt that QV data were automatically filtered in accordance with regional reimbursement policy. We also received recommendations from clinicians at the HND Centre to check QV frequencies against hospital calendar data. Therefore, visit frequencies were manually extracted from the scheduling system.

QV data were cleaned and analysed in R software V.1.1.442 to extract visit frequencies. Calendar data were manually extracted, and the visit type and date were entered into a .csv file.

### Steps 3 and 4: develop care process maps and time estimates for activities

Initial process maps were provided by HND staff, and non-participatory contextual observations were performed to refine these maps and estimate the duration of staff involvement in each activity (steps 3 and 4). Observational data were collected over a 10-day period. GK, RM and IG shadowed HND staff and collected data using an Excel-based tool on handheld devices. Each patient visit in the CDVC was mapped as an activity. Observed events were documented as 'activity steps' associated with a visit type, and durations of human resource (HR) involvement were measured. Data were uploaded from the handheld devices into a cloud database. No patient identifying information was collected. R software V.1.1.442 was used to generate process maps.

Each process map was presented to staff stepwise to minimise reporting biases. Staff were first shown the steps performed in each map and were asked to add steps overlooked or remove those not routinely performed in practice. Staff provided their own time estimates for each step, and later they were shown time estimates from contextual observations. Differences were discussed and appropriate modifications were made to produce the final maps.

### Step 5: estimate the cost of resources

To estimate the cost of resources involved in HND care processes, managerial accounting documents were obtained from two hospital controllers. Three cost sheets were provided which included costs for HND care.

The first sheet, a staffing sheet, detailed cost information for non-physician staff, including salary, overtime, sick leave, education-based payment, bonuses and vacation pay. For physicians, only salary data were available. Clinical and economic staff provided an estimate of non-salary physician costs as 11% of physician salary. According to the Swedish norm, social insurance cost was applied according to controllers' instruction at 47% of HR salary costs.

The second sheet was the HND Centre's chart of accounts, and it depicted revenues and costs generated by patients in HND care. HR cost information from this sheet was not used because the staffing sheet data were more precise. Facilities space costs in this sheet were specific for the HND Centre, therefore these costs were allocated on a square metre basis after taking physical measurements of the premises.

Lab, X-ray and pharmaceutical costs associated with the HND Centre were not comprehensively covered in the chart of accounts, but through a software system called Intelligence purchased by the hospital. Intelligence outputs were generated by external Business Intelligence (BI) firm contracted by Stockholm County to generate routine cost estimates, based on Intelligence outputs, of visits and procedures for DRG valuation purposes. The third sheet provided Intelligence estimates of 12 relevant cost pools driven to the HND Centre. Three of these pools—personnel, facilities space and pharmaceutical

cost—were driven at a standard fixed price per visit used across the entire cardiology clinic. These standard prices are manually and independently updated in Excel semiannually by controllers assigned to each clinic. In our TDABC analysis, we assigned pharmaceutical costs to visits at this rate because we had no better information. The remaining cost pools included X-rays performed within the hospital and also various lab costs outsourced to another hospital. X-ray costs and invoices from outsourced lab work are directly linked to visits and patients within the HND Centre via Intelligence. In this analysis, clinical chemistry lab costs at the HND Centre were distributed evenly among physician visits. Other lab, X-ray and pharmaceutical costs were distributed among in-person visits. These allocation methods appropriately matched care delivery according to clinicians at the HND Centre.

### Step 6: estimate the capacity cost rates of resources

The capacity cost rate (CCR) is a resource's annual cost divided by its annual capacity, that is, the time available for work over 1 year. CCRs were calculated for nurses, doctors and USKs.

Theoretical annual capacity includes time not involved in care delivery, that is, breaks, idle time, repairs, training, education, etc. Practical capacity adjusts the theoretical capacity to include only time available for service delivery activities.

The staffing sheets provided capacity data in full-time equivalents (FTEs) for non-physician staff, including paid leave, sick leave, parental leave, and education-based activities. Leave data were not broken down by staff type, but provided on the aggregate. Therefore, only a single practical capacity adjustment could be estimated for all staff types. Given the limitations of the capacity data from the economy department, another approach was taken in parallel for practical capacity estimates based on the calendar data, which contained capacity data for all staff types, including physicians. These data showed the number of nurse and physician FTEs present each day at the HND Centre—the practical capacity, if break time is subtracted. Both calendar and staffing sheet data were explored, and the data set that provided the most granular capacity estimate was selected. Breaks were removed from clinical time for all staff, according to the controllers' recommendation, at a rate of 1 hour/day per FTE.

Using these practical capacity estimates and the annual resource costs obtained in Step 5, the CCRs were calculated.

### Step 7: calculate the total cost of care

To complete the TDABC analysis, cost estimates of selected care delivery activities and the total cost of HND care were calculated. The estimated HR cost of each activity was calculated from the CCRs and resource time estimates obtained in steps 4 through 6. Remaining costs were driven to each activity using appropriate cost drivers. The frequencies of each activity were multiplied by their



**Table 2** Annual activity frequency, marginal cost and total annual cost

Process	Annual count	Cost* (€)	Annual cost† (€)
New visit	143	367	52 528
Nurse telephone consultation	1545	51	78 286
Nurse visit	278	211	5854
Physician telephone consultation	159	60	9469
Physician visit	151	297	44 780
Team conference	240	115	27 470
Team visit	478	369	176 567
Uncaptured capacity			24 138
Total			471 791

\*The cost of each of these activities in the economy department price list was €187.2.

†Arithmetic comes out differently as decimal values are not shown in the table.

respective TDABC cost estimate to estimate the annual cost of each activity over a 1-year period. The sum of these costs was the estimated annual cost of the HND Centre.

### Patient and public involvement

This research was done without patient involvement. Given that this research was focused on the organisational development of a hospital from a managerial accounting perspective, patient involvement was not appropriate. Patients were not invited to comment on this study design and were not consulted to develop or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

## RESULTS

### Frequencies of activities in the CDVC

Seven outpatient care delivery activities were identified at the HND Centre. These activities and their frequencies, generated from the calendar data, are listed in table 2. New visits were patients' first visits to the HND Centre, where they met both a nurse and a physician separately.

During team visits, the patient met a physician and a nurse together. Team conferences involved doctors, nurses and USKs meeting without the patient to discuss the patient's care plan.

The calendar data listed substantially more visits than the QV data. For example, 63 new visits were identified in the QV data, while the calendar data reported 143 new visits. Of note, 1545 nurse phone calls were identified in the calendar system, while 1109 were identified in the QV data. Secretarial staff at the hospital informed us that this happens because the county government mandates which visits qualify to be registered in the QV data for remuneration purposes. The model results were substantially lower than the HND Centre's annual budget when QV data were used. Given that the actual visits performed in practice better represent the cost of care, the calendar data were input to the model.

### Process maps and time estimates for activities

Staff-validated process maps are presented in tabular form in online supplementary appendix A, which include each step within activities and the respective duration of time HR were involved.

### Cost estimates

HR cost estimates are provided in table 3. The monthly cost of one FTE physician, nurse and USK was €5550, €3022.46 and €2913.63, respectively.

The costs of non-HR are provided in table 4, along with parameters used to drive costs to activities.

### Capacity estimates and CCR

According to staffing sheets, the total FTEs, including non-care-delivery activities, for all non-physician staff was 3.82 FTEs. Non-physician time allocated for clinical activities (no training, education, vacation, etc) amounted to 2.89 FTEs. Practical capacity was estimated at 75.5% (2.89/3.82) of theoretical capacity for each non-physician resource. Therefore, 1.9 (75.5% of 2.54) nurse FTEs were assigned work clinically for 252 work days in 2017. However, the calendar data indicated that the HND Centre was in operation for only 231 days during 2017, with an average of 1.76 nurses present for clinical work each day of operation. Therefore, according to these

**Table 3** Human resource capacity estimates and CCRs

	A. Monthly cost (€)	B. FTEs	C. (A × B × 12) Annual clinical care cost (€)	D. Care delivery FTEs	E. Days present at the HND Centre	F. (D × E) Total care delivery days	G. Work hours/ week	H. ((G ÷ 5)–1) work day hours – 1-hour break	I. (F × H) Care delivery hours/ year	J. ((C ÷ I) ÷ 60) CCR (€/min)
Physician	5550	1	66 600	1	202.5	202.5	50	7	1417.50	0.78
Nurse	3022	2.79	101 359	1.76	231	406.6	37	6.4	2594.70	0.65
USK	2913.63	0.15	5381	0.116	231	26.9	38.25	6.7	178.6	0.5

CCR, capacity cost rate; FTEs, full-time equivalents; HND, heart, nephrology and diabetes.

**Table 4** Non-human resource costs and corresponding drivers

Resource	Source	Cost (€/month)	Driver
Facility costs	HND Centre Chart of Accounts	4923	Minutes per square metre
Social welfare	Staffing sheets	7979	Personnel
Clinical chemistry	BI firm Intelligence output	3112	Physician visits
Pharmacy	BI firm Intelligence output	3851	Visits
X-ray	BI firm Intelligence output	1440	In-person visits
Other lab costs	BI firm	1033	Visits

BI, Business Intelligence; HND, heart, nephrology and diabetes.

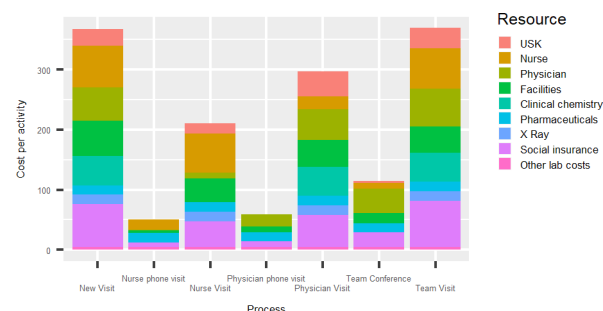
data, 1.76 nurse FTEs each provided 231 days of clinical work in 2017. For USKs, the practical capacity adjustment of 75.5% obtained from the economics department was used to adjust 1.02 FTEs allocated to clinical time to 0.77 FTEs for each of 231 days of operation. The calendar also showed that one physician was on staff for 202.5 of the 231 days the Centre was in operation. Calendar capacity data for nurses (1.76 FTEs for 231 days), USKs (0.77 FTEs for 231 days) and physicians (1 FTEs for 202.5 days) were used to calculate CCRs. Capacity estimates are more valid when based on what happened in practice as opposed to a 75.5% capacity adjustment based on economic department financial statements. For USK clinical time, the 0.77 FTE figure was used.

USKs, nurses and physicians were expected to work 37, 38.3 and 40 hours per 5-day work week, respectively, including the 1-hour daily breaks. Estimates of theoretical capacity, practical capacity, annual cost and CCRs for each resource are provided in [table 3](#).

### Total cost of care

The marginal cost and total annual cost of each activity are provided in [table 1](#), together with the total annual cost of the HND Centre. [Figure 1](#) presents the TDABC costs per activity stratified by resource. The hospital's intelligence software provides a single estimate, €188.40 per visit, for all HND activities, compared with €157.58 from this analysis. This includes a fixed estimate of €98.90, €53.50 and €14.70 for personnel, facilities space and pharmaceutical cost, respectively. Beyond this estimate, the hospital's chart of accounts and the BI firm's statements did not provide visit-specific cost estimates.

The TDABC model's estimate of staff cost was €170 409. This cost together with social welfare costs amount to €233 585 or 73% of the BI firm's staff cost estimate of



**Figure 1** Cost per process, 2017. This figure presents the resource-stratified cost of each individual activity/patient visit provided at the HND Centre. Costs are presented in euros. HND, heart, nephrology and diabetes; USK, undersköterska.

€310 942. The model estimated total annual costs of the HND Centre to be €471 791 or 80% of the BI estimate of €592 387.

The model accounted for 91% of clinical nurse capacity, 94.7% of physician capacity and 89.9% of clinical USK capacity. A total of €24 138 in HR costs allocated to the HND Centre was not captured by the TDABC, or 10% of HR costs.

### DISCUSSION

This article applied TDABC to cost the care for patients with multiple chronic conditions, where pathways are not yet discernable. Slight methodological adaptations were required for this particular patient group, stratifying costs by activity and resource. Management incorporated the insights from this analysis into the development of their hospital strategy, as discussed later. In the absence of integrated data infrastructures that can link patients and resources across financial, clinical and process data sets, the scalability of this method will be difficult.

Specific methodological features made this TDABC analysis possible. Frequencies of clinical events were used in the absence of established care pathways. In accordance with the methodological recommendations,<sup>20</sup> triangulation of data sets allowed for the identification and exploitation of strengths and weaknesses of data sets, TDABC methods and hospital costing structures. While other TDABC applications generally produce single cost estimates of activities,<sup>20</sup> this analysis generated an annual cost estimate of the HND Centre itself, reconciled against existing hospital financial systems. The hospital used the same cost estimate for every activity included in this analysis, €188.40. This overestimated the average cost of HND care visits, which in this analysis was estimated to be €157.58. Moreover, the TDABC output provided separate cost estimates for each activity, stratified by resource ([figure 1](#)).

A key value of a TDABC analysis lies in its ability to support managerial decision-making.<sup>20</sup> While the HND Centre resonated with values of person-centred care at the hospital,<sup>29</sup> management had down-prioritised the Centre in the context of budgetary constraints. The

findings of this research were discussed with the hospital management team who appreciated the method's ability to identify where costs were incurred in the CDVC for patients with this level of complexity. As a consequence, the hospital chose the Centre as one of five initiatives earmarked by the hospital for continued development. With respect to the HND Centre itself, the monetary benefit of replacing in-person visits with telephone consults was made measurable. The combined costs of nurse and physician visits exceeded that of a team visit, and the unit now prioritises combining nurse visits with doctor visits. USKs can be trained to enter information from physician visits into quality registers, shifting this task away from nurses. Even if many of the costs involved in this analysis could be considered unavoidable, efficiency can still be improved by optimising care delivery and resource use. These TDABC results will be developed further and integrated with the ongoing RCT, to draw a value-based comparison between IPU and traditional care.

Important areas for information systems development were brought to the attention of management. DRG estimates of outpatient visits were too aggregated for managerial decision-making. Discrepancies were found between QV data and the scheduling system because the QV data set was modified for reporting purposes, and not reliable for managerial decision-making. In this study, the electronically inaccessible calendar data were used instead, which were manually extracted—a time-consuming and unreliable approach to data collection. This reflects contrasting priorities of the hospital economics department, where financial reporting is systematically prioritised over managerial decision-making. Second, hospital controllers manually and independently calculated visit prices in excel at the department level, which characterises the need for integrated data infrastructures and better automation. Process data were insufficiently available. Processes were occasionally mapped for presentations, but not for analytical purposes and were not integrated with economic and clinical event data. Limited data access, difficulties with interpretation and data set discrepancies have previously been identified as problems in hospital data infrastructures.<sup>30</sup>

These issues affect the scalability of TDABC. Care process owners should systematically collect processes data, which should be well-integrated with economic and clinical data. Data integrated into municipal databases allow for analyses that span organisational boundaries for any multimorbidity combination. This method is already developing in the Halland County in Sweden, where they refer to this approach as Patient Encounter Costing, which is TDABC supported by strong data infrastructures, but lacks a peer-reviewed evidence base. Developing such solutions from within healthcare systems avoids dependence on external suppliers whose solutions are often logistically challenging to adapt to context<sup>31 32</sup>—a concern when dealing with complex care processes.

These solutions often come with a large cost and risks of market withdrawal.<sup>31 32</sup>

A few cautionary points should be raised. First, visit frequencies within unstandardised complex care may vary considerably from year to year. The degree of instability will proportionally weaken the stability of cost estimates. Second, staff need to feel safe and secure in their employment with a shared vision of the importance of strong costing systems. Otherwise, there is a risk of misleading reporting of process data, including duration of activities. Third, expert physicians had already identified criteria for the HND condition and selected patients for an RCT. Depending on the medical condition, it can take time to gather relevant expertise and reach consensus on how to define medical conditions. A hospital-wide TDABC implementation has not been thoroughly described in the published literature, and related challenges remain to be documented. Perseverance, staff involvement and integrated data infrastructures are key points to consider for organisations intending to develop and integrate TDABC cost systems.

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**Acknowledgements** The authors would like to thank the staff of the study-setting hospital's economy department and the HND Centre for their support throughout the research process. Also, they thank members of the Clinical Management Research Group at the Medical Management Centre, Karolinska Institutet, for feedback on earlier drafts of this article.

**Contributors** GK, RM, CS, JS and PM conceived the study. GK, RM, CS, JS, PL, CG and PM designed the study. GK, RM and IG collected data with the support of CS, JS and PM. GK, RM, JS and IG analysed the data that were iteratively discussed and interpreted with all authors. GK drafted the manuscript that was first revised iteratively by CS, JS and PM, and then by all authors. All authors approved the final version and agreed to be held accountable for the work.

**Funding** This work was supported by FORTE (2014-4957); Vårdalstiftelsen (2014-0094), the Kamprad Family Foundation (grant number never provided by the funder) and a block grant from Karolinska Institutet (2-3591/2014). PM was also financially supported by Strategic Research Area Health Care Science, Karolinska Institutet/ Umeå University.

**Competing interests** None declared.

**Patient consent for publication** Not required.

**Ethics approval** The study was approved by the Regional Ethics Committee (Diary Numbers 2014/384-31/1 and 2017/999-31/2).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. Technical appendix, R code and data are available from the corresponding author upon request, as long as the data sharing process is in compliance with GDPR policy.

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