A Cost Analysis of Colonoscopy using Microcosting and Time-and-motion Techniques

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BACKGROUND: The cost of an individual colonoscopy is an important determinant of the overall cost and cost-effectiveness of colorectal cancer screening. Published cost estimates vary widely and typically report institutional costs derived from gross-costing methods.

OBJECTIVE: Perform a cost analysis of colonoscopy using micro-costing and time-and-motion techniques to determine the total societal cost of colonoscopy, which includes direct health care costs as well as direct non-health care costs and costs related to patients' time. The design is prospective cohort. The participants were 276 contacted, eligible patients who underwent colonoscopy between July 2001 and June 2002, at either a Veterans' Affairs Medical Center or a University Hospital in the Southeastern United States.

MAJOR RESULTS: The median direct health care cost for colonoscopy was $379 (25%, 75%; $343, $433). The median direct non-health care and patient time costs were $226 (25%, 75%; $187, $323) and $274 (25%, 75%; $186, $368), respectively. The median total societal cost of colonoscopy was $923 (25%, 75%; $805, $1047). The median direct health care, direct non-health care, patient time costs, and total costs at the VA were $391, $288, $274, and $958, respectively; analogous costs at the University Hospital were $376, $189, $368, and $905, respectively.

CONCLUSION: Microcosting techniques and time-and-motion studies can produce accurate, detailed cost estimates for complex medical interventions. Cost estimates that inform health policy decisions or cost-effectiveness analyses should use total costs from the societal perspective. Societal cost estimates, which include patient and caregiver time costs, may affect colonoscopy screening rates.

KEY WORDS: cost analysis; colonoscopy; colorectal cancer; microcosting; time-and-motion.
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INTRODUCTION

All recommended colorectal cancer screening strategies involve colonoscopy as either an initial or confirmatory test for the presence of colorectal adenomas and cancer[1, 2]. The cost of an individual colonoscopy has been shown to impact the cost[3] and cost-effectiveness[4–6] of colorectal cancer screening. Published estimates of colonoscopy cost vary widely[7–10]. An accurate estimate of the cost for an individual colonoscopy is important for making health policy decisions concerning colorectal cancer screening.

Most published estimates for colonoscopy cost use gross-costing methods and are derived from institutional databases, especially Medicare reimbursement[9,11–13]. Microcosting techniques directly measure resources consumed during a medical intervention and are the preferred method for measuring cost according to the US Panel on Cost-Effectiveness in Medicine[14]. Time-and-motion studies prospectively collect information through direct observation of time and other resources consumed during a medical intervention. Microcosting studies have been performed for sigmoidoscopy[15,16], but no microcosting analysis using time-and-motion techniques has been published for colonoscopy.

Extant cost estimates of colonoscopy calculate institutional cost—the cost to the hospital or clinic performing colonoscopy. Institutional costs may be appropriate for reimbursement or local management decisions, but total cost—the cost to society of a health care intervention—is recommended for health policy and cost-effectiveness analyses[14]. The total cost of a medical intervention includes direct health care costs (costs directly generated by the intervention) as well as direct non-health care costs (necessary costs not directly generated by the intervention including costs related to informal caregivers' time) and costs related to patients' time (e.g., absence from work, childcare expenses)[14]. To measure the total cost for colonoscopy and account for all of these cost components, we performed a microcosting analysis of colonoscopy using time-and-motion techniques.

MATERIALS AND METHODS

We performed a microcosting analysis from the societal perspective using direct observation of all transactions involved in colonoscopy. A transaction is any exchange between two parties that constitutes part of a medical intervention[17].

Observations were made at a University Hospital and a Veterans Administration (VA) Medical Center. The study was conducted according to the recommendations of the US Panel on Cost-Effectiveness in Health and Medicine[14] and was part of the Nashville Colorectal Health Study, an IRB-approved study. All data were collected during fiscal year (FY) 2002 (July 2001 through June 2002); costs are reported in 2002 US dollars.

Patient Recruitment

Potential participants were identified through weekly review of the endoscopy schedules at both hospitals. All patients 18 years of age or older scheduled for colonoscopy at either hospital during FY 2002 were considered for inclusion. Exclusion criteria included inability to give informed consent or speak English, diagnosis of a hereditary colorectal cancer syndrome or inflammatory bowel disease, and previous history of adenomatous polyps, colorectal or other cancer except nonmelanoma skin cancer. Telephone contact of identified patients was attempted before their colonoscopy. Contacted patients were evaluated for eligibility and willingness to participate. All eligible patients were asked to give written informed consent. Consented patients were interviewed by telephone to collect demographic information.

Micro-costing Analysis

A comprehensive list of resources consumed during colonoscopy was compiled through direct observation of the colonoscopy process at each institution, interviews with clinical personnel, and consultation with experts in process improvement and activity-based costing. A uniform process flow diagram for colonoscopy was constructed (Fig. 1) that allowed comparison of transactions between hospitals. Additional details of microcosting and time-and-motion methods are included in the Appendix.

We called transactions involving direct patient care "caregiving transactions" and called all other transactions "coordinating transactions" (Fig. 1). One study nurse accompanied all participants at both hospitals through their entire procedure

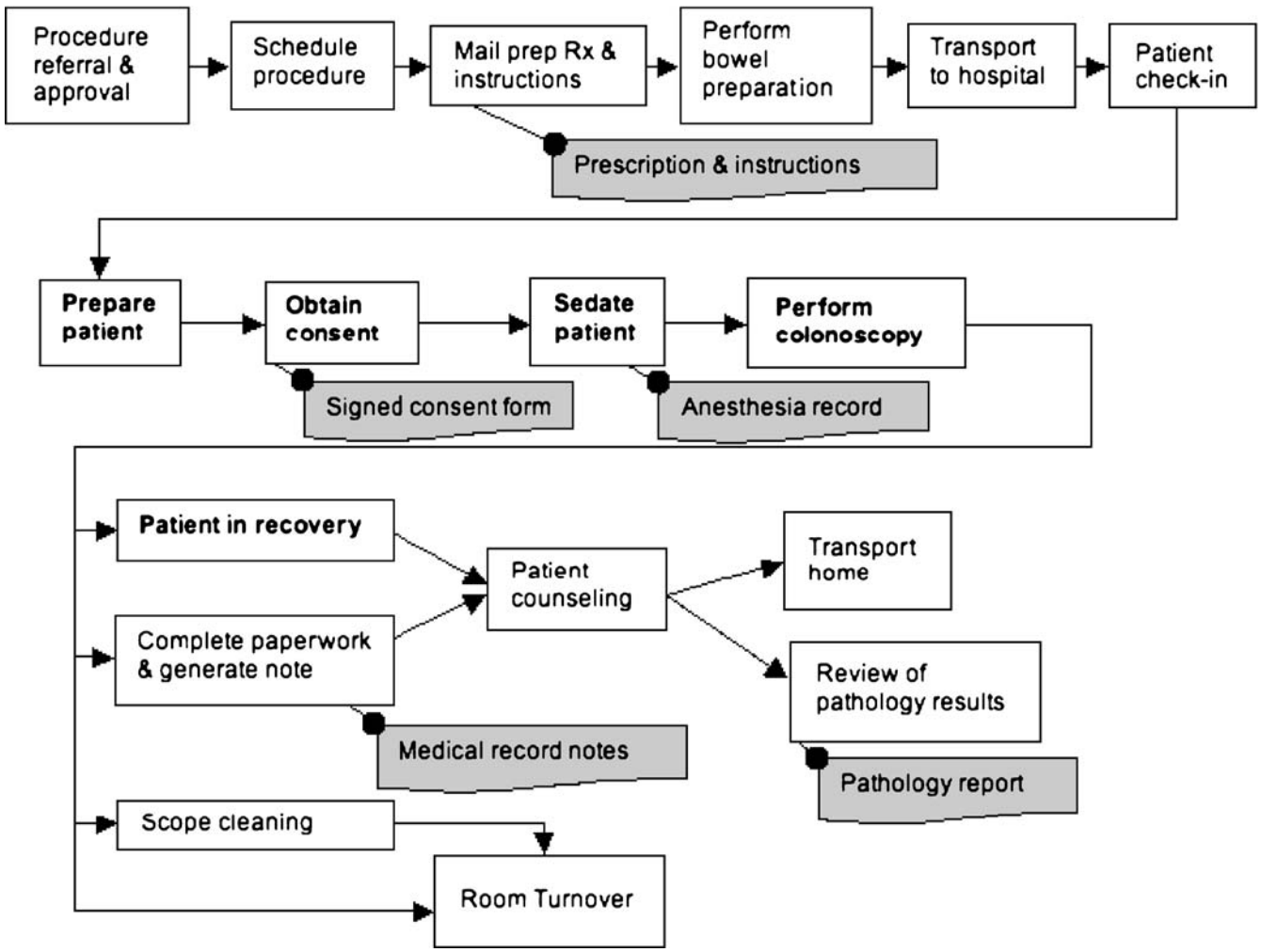

Figure 1. Transactions associated with scheduling, performing, and following-up a colonoscopy. This diagram illustrates all the transactions constituting a screening colonoscopy. Each box represents one transaction; *arrows* demonstrate the temporal relationship between transactions. *Bold font* indicates caregiving transactions that involve direct provision of patient care. *Regular font* indicates coordinating transactions that involve supporting activities. *Shaded boxes* identify medical documentation that is generated during certain transactions.

and recorded the duration of all caregiving transactions to the nearest minute. She recorded the time that each type of health care worker spent with each patient to the nearest minute using a standardized data collection instrument. The same nurse observed and recorded the amount and types of medication administered and wasted as well as the number and kinds of equipment used for each procedure. One author (RMN) retrospectively reviewed all procedure notes to verify the appropriate CPT code for each colonoscopy. Medicare reimbursement is the most common source of published cost estimates and provides a reference against which to gauge our results.

We assumed that coordinating transactions did not vary in duration according to patient characteristics. One author (SGH) observed a convenience sample of at least 20 instances of each coordinating transaction at both hospitals. The mean duration of each coordinating transaction was calculated to the nearest minute and used in calculating the cost of each colonoscopy. For transactions performed by several different types of health care personnel, separate sets of observations were made for each personnel type.

Fixed costs (e.g., maintenance, utilities, office supplies, nonendoscopic equipment, endoscope cleaning, suite administration) and capital equipment costs (e.g., endoscopes, light sources, processors, beds, monitors) were derived in collaboration with each hospital's financial department and confirmed by equipment manufacturer representatives for FY 2002. Notes in Table 1 detail components of these costs. Fixed costs per procedure were calculated by distributing the total fixed costs equally among all GI procedures performed during the study period at each hospital. A weighted average accounting for the varying durations of different endoscopic procedures was not possible given our data collection methods, but distributing fixed costs evenly was reasonable because many fixed costs do not vary with procedure length. Procedure-level equipment costs were calculated by apportioning total equipment costs to each procedure based on the total number of procedures performed using each equipment resource (Table 1).

Patients completed a questionnaire on the day of their procedure that asked them to list distance traveled and costs incurred for travel, costs for child or elder care, and time taken out of the patients' and their drivers' usual schedules for the procedure (patients usually require drivers because colonoscopy involves conscious sedation). Patients' and, where applicable, drivers' time taken for colonoscopy were recorded in half-day increments.

Each hospital's financial department provided average annual compensation (salaries plus fringe benefits) for all job classes. Compensation was converted to a per-minute rate based on the average number of hours per week and weeks per year worked in each job class at each hospital. Per-minute rates were inflated by the hospital overhead rate charged for administrative costs beyond the endoscopy unit (University Hospital 30%, VA Medical Center 44%). Notes in Table 1 show details of these calculations.

Per-minute compensation rates were also inflated by each unit's capacity utilization (i.e., fraction of productive facilities in use over time). Capacity utilization affects labor costs because revenue generated from reimbursable services must pay for the time that employees must spend performing nonreimbursable activities. We used operating utilization (the fraction of available operating time actually spent performing procedures) as a proxy for capacity utilization. To estimate operating utilization, we divided the estimated number of hours spent performing procedures during FY 2002 by the total number of hours available for procedures at each hospital during FY 2002. Estimates of capacity utilization required measurement of procedure length for noncolonoscopy endoscopic procedures; the Appendix contains complete methods for measuring capacity utilization. After adjustments for administrative overhead and capacity utilization (see Table 1 notes), labor costs were calculated by multiplying the employee time for each procedure by the appropriate per-minute rate.

Patients' and drivers' time was valued at $182.40 per day based on the average wage paid to employees in the East-Central census tract in 2001[18]. Transportation costs were valued at 34.5¢/mile traveled to and from each hospital based on IRS valuation of work-related driving time in 2001[19]. The cost per unit of the bowel preparation and procedural medications used and wasted was obtained from each hospital's pharmacy.

We calculated the direct health care cost of each colonoscopy by summing time and resource data from all caregiving transactions, coordinating transactions, and other fixed and capital equipment costs. Direct non-health care costs and patient time costs were calculated from questionnaire results and combined with the direct health care costs to calculate the total societal cost of each procedure. In addition, average national Medicare reimbursement for 2002 was used to determine the mean Medicare reimbursement for procedures preformed in this study.

Table 1. Cost Rates for Personnel, Patients, and Materials Related to Colonoscopy

	University Hospital	VA Medical Center
Personnel ($/min)[a]		
GI attending	3.51	4.31
GI fellow	0.50	0.61
Surgical resident	0.47	0.57
Nurse	1.27	1.89
GI technician	0.68	1.39
Pharmacy technician	–	1.12
Clerical worker	0.69	0.93
Patient		
Patient/Driver time ($/day)[b]	182.40	182.40
Mileage ($/mile)[c]	0.345	0.345
Other expenses	From data	From data
Endoscopy Suite		
Forceps/snares ($/device)	16.75/18.60	17.00/17.22
Medications ($/procedure)[d]	From data	From data
Fixed costs ($/procedure)[e]	67.94	42.73
Capital costs ($/procedure)[f]	44.20	46.77

[a] *(local per-minute wage + benefits) × (overhead) / (time worked) × (capacity utilization)*
[b] *(8 h day) × (BLS mean wage for East-Central region + 20% benefits) × (30% overhead) / (37 h/week worked for 40 h pay) × (0.80 capacity utilization)*
[c] *IRS travel expense rate*
[d] *Values cannot be divulged secondary to contractual agreements*
[e] *Non-capital equipment + suite administration + utilities + cleaning + hospital overhead*
[f] *Includes endoscopy equipment and cleaning machines, image archive system, beds, and vital sign monitors*

Statistical Analysis

Demographic characteristics for consented, refusing, and uncontactable patients were compared using Wilcoxon rank sum tests for continuous variables, and chi-square or Fisher's exact test for categorical variables. The participants' characteristics were similarly compared between hospitals.

We compared the median total, direct health care, and patient time cost per colonoscopy between hospitals using the Wilcoxon rank sum test. We queried for cost differences between CPT billing codes using the Kruskall-Wallis test.

We performed a one-way sensitivity analysis of capacity utilization's influence (at 40, 60, and 80%) on each hospital's labor costs, assuming that an identical number of health care workers, overhead, and capital equipment were required at all levels of capacity utilization.

RESULTS

Study Population

Of the 376 contacted, eligible patients, 274 (73%) gave consent and were included in the study (Fig. 2). We found no statistically significant differences ($p>0.05$) in gender or reason for referral among contacted patients compared with uncontactable patients or patients who refused consent. Uncontactable compared to contacted patients were younger (55.7 versus 57.8, $p=0.03$) and more likely to be nonwhite (26 versus 15%, $p<0.001$). Refusers compared with consented patients were more likely to be nonwhite (35 versus 11%, $p<0.001$). The study sample comprised 118 VA Medical Center patients and 156 University Hospital patients. Detailed characteristics of study patients are presented in Table 2.

Table 2. Characteristics of Study Participants

Characteristic	University Hospital (*N*=156)	VA Medical Center (*N*=118)	Combined (*N*=274)
Age (year)			
Median (25%, 75%)	55.4 (50.2,63.4)	58.3 (52.3,67.8)	56.7 (50.8,66.4)
Gender*			
Male	53 (34%)	113 (96%)	166 (61%)
Race			
White	144 (92%)	100 (85%)	244 (89%)
Black	6 (4%)	17 (14%)	23 (8%)
Other	6 (4%)	1 (1%)	7 (3%)
Income ($/year)*			
Unknown/no response	25 (16%)	14 (12%)	39 (14%)
0–15,000	8 (5%)	25 (21%)	33 (12%)
15,001–30,000	7 (5%)	38 (32%)	45 (16%)
30,001–50,000	23 (15%)	24 (20%)	47 (17%)
30,001–75,000	34 (22%)	12 (10%)	46 (17%)
75,001–100,000	21 (13%)	2 (2%)	23 (8%)
100,001–150,000	20 (13%)	2 (2%)	22 (8%)
>150,000	18 (12%)	1 (1%)	19 (7%)
CPT Code*			
G0105/0121 (screening)	52 (33%)	18 (15%)	70 (26%)
45378 (diagnostic)	45 (29%)	41 (35%)	86 (31%)
45380 (with biopsy)	34 (22%)	26 (22%)	60 (22%)
45385 (with polypectomy)	25 (16%)	33 (28%)	58 (21%)

*P value for comparison between hospitals<0.05

Cost Outcomes

Table 3 shows primary study outcomes. The median total direct health care cost of all colonoscopies was $379. This figure less out-of-pocket costs for bowel preparation medication corresponds to the total colonoscopy cost from the institutional perspective. The total societal cost also includes direct non-health care costs (e.g., travel costs, costs of informal caregivers' time) and costs related to patients' time. The median direct non-health care and patient time costs for all colonoscopies were $226 and $274, respectively; the median total societal cost of all colonoscopies was $923.

By comparison, national average Medicare reimbursement rates for screening colonoscopy, diagnostic colonoscopy, colo-

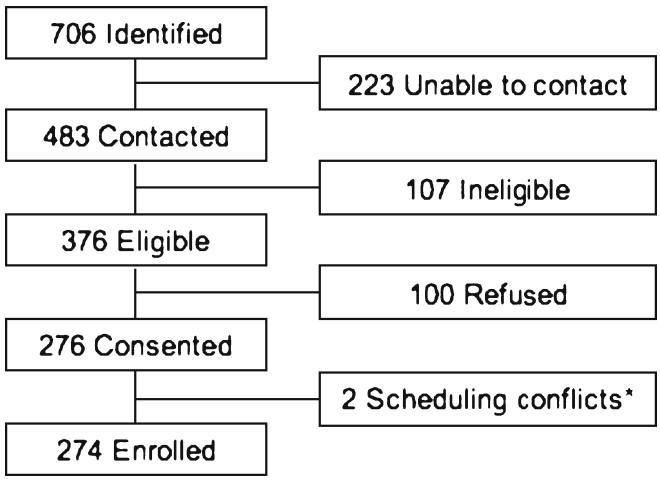

Figure 2. Patient recruitment diagram. *Asterisk* signifies patients that were scheduled for colonoscopy at the same time as other study participants.

Table 3. Median Costs for Observed Colonoscopies by Hospital

Hospital	Direct Health Care Costs ($)	Direct Non-Health Care Costs ($)*	Patient Time Costs ($)*	Total Cost ($)[a]
University Hospital	376 (347,408)[a]	189 (186,206)	368 (186,368)	905 (760, 994)
VA Medical Center	391 (331,483)	288 (257,358)	274 (182,274)	958 (860,1099)
Combined	379 (343,433)	226 (187,323)	274 (186,368)	923 (805,1047)

[a]*Median (25th, 75th percentile)*
**P* value for comparison between hospitals<0.05

noscopy with biopsy, and colonoscopy with polypectomy in 2002 were $538, $575, $612, and $657, respectively [20]. Table 4 lists corresponding CPT codes. The expected mean Medicare reimbursement for the colonoscopies in our study correcting for CPT code would have been $592.

Total direct health care costs did not differ significantly between hospitals. Direct non-health care costs and patient-time costs did differ significantly between hospitals, but total societal cost did not (Table 3). Only direct health care costs were found to vary significantly between procedures assigned different CPT codes (Table 4). This significant variation in direct health care costs according to CPT code persisted after adjustment for the hospital where colonoscopy occurred (p=0.001).

When analyzed by cost center, the two largest components of direct health care costs at both hospitals were GI attending physician time and nursing time, which accounted for 29 and 25% of the direct health care costs at both hospitals, respectively. At both hospitals, combined labor costs constituted approximately 66% of total direct health care costs; fixed and capital costs constituted approximately 24%.

The components of the direct health care costs were also analyzed by transaction (Table 5). The procedure itself (comprising transactions "prepare patient" through "patient in recovery" in Fig. 1) accounted for the largest proportion of direct health care costs, although its relative contribution varied substantially between hospitals (Table 5).

Table 4. Median Costs for Observed Colonoscopies by CPT Billing Code

CPT Code	Direct Health Care Costs ($)*	Direct Non-Health Care Costs ($)	Patient Time Costs ($)	Total Cost ($)
G0105/0121 (screening)	358 (333,387)[a]	192 (185,291)	365 (186,368)	904 (753,992)
45378 (diagnostic)	366 (331,407)	252 (187,343)	274 (186,368)	899 (774,1047)
45380 (with biopsy)	385 (355,437)	198 (187,316)	274 (186,368)	929 (811,997)
45385 (with polypectomy)	445 (394,521)	253 (188,320)	274 (182,365)	982 (882,1122)

[a]*Median (25th, 75th percentile)*
**P* value for comparison between CPT codes<0.05

Table 5. Percentage Contributions to Direct Health Care Cost for Observed Colonoscopies by Transaction

	University Hospital ($)	VA Medical Center ($)	Combined ($)
Transactional Costs			
Scheduling and mailing instructions and/or bowel prep	38 (10%)	11 (3%)	26 (7%)
Bowel prep	20 (5%)	12 (3%)	17 (4%)
Patient check-in	7 (2%)	2 (<1%)	5 (1%)
Procedure (preparation, consent, sedation, colonoscopy)	139 (36%)	258 (62%)	190 (48%)
Recovery	25 (6%)	25 (6%)	25 (6%)
Paperwork/note generation	23 (6%)	9 (2%)	17 (4%)
Room turnover	6 (2%)	4 (<1%)	5 (1%)
Scope cleaning	7 (2%)	5 (1%)	7 (2%)
Patient counseling	7 (2%)	<1 (<1%)	4 (1%)
Pathology review	2 (<1%)	<1 (<1%)	2 (<1%)
Non-transactional costs			
Fixed	68 (18%)	43 (10%)	57 (14%)
Capital equipment	44 (11%)	47 (11%)	45 (11%)
Mean direct health care costs	386	416	399

Sensitivity Analysis

We calculated capacity utilization at the University Hospital and VA Medical Center as 59 and 48%, respectively. Patient time costs and direct non-health care costs were independent of personnel compensation, so a one-way sensitivity analysis affected only direct health care costs. The direct health care cost per colonoscopy at the VA Medical Center was greater than at the University Hospital in the base case, but cost per colonoscopy at the VA Medical Center was approximately $34 less than at the University Hospital if both hospitals operated at 60% capacity utilization.

DISCUSSION

This study demonstrates that total colonoscopy cost depends greatly on whether costs are evaluated from the societal or institutional perspective. In this study, total direct health care costs less out-of-pocket costs for bowel preparation medication provide an accurate estimate of the institutional cost of colonoscopy. Institutional cost estimates are useful for making local management or billing decisions. Total societal cost is the appropriate perspective for decisions about health policy and public health. In particular, population-level cost-effectiveness and cost-utility analyses should adopt the societal perspective. The societal perspective also highlights the contribution of patients' and caregivers' time, which are important barriers to achieving high colorectal cancer screening rates [21].

Previous estimates of colonoscopy cost [8,13,22–24] have used an institutional perspective that did not measure direct non-health care or patient time costs. While this study does not evaluate cost effectiveness, the finding that direct health care costs constitute less than 50% of total societal colonoscopy costs suggests that conclusions about the relative cost effectiveness of colorectal cancer screening may be altered by the inclusion of direct non-health care and patient time costs.

Future cost estimates of colonoscopy should specify whether the societal or institutional perspective is employed; estimates of societal cost must include direct non-health care and patient time costs.

Most published cost estimates of colonoscopy are based on analysis of Medicare reimbursement [9,11–13]. Medicare reimbursement was not designed to provide cost estimates of medical interventions and so is not directly comparable to the direct health care cost estimates in this study. Discrepancy between median Medicare reimbursement and median direct health care costs is not surprising given the differences between these two measures. Unlike cost estimates based on Medicare reimbursement, our results do not presuppose a relationship between cost and charge. The finding that the direct health care costs of colonoscopy varied significantly according to CPT billing code may support the use of CPT billing codes as surrogates for procedural complexity.

Process flow diagramming (Fig. 1) and microcosting techniques allowed meaningful comparison of the components of direct health care costs at the two hospitals in our study (Table 5). Costs for caregiving and coordinating transactions were distributed differently at the two hospitals, but total direct health care costs were similar. These results underscore the important effects that health system organization, personnel type, and clinic architecture have on direct health care costs.

While the median direct health care costs for colonoscopy at the University Hospital and VA Medical Center did not differ significantly (Table 3), cost distribution differed substantially when analyzed by transaction type (Table 5). A greater proportion of the costs were attributable to caregiving transactions at the VA Medical Center when compared to the University Hospital (62 vs 36%), where coordinating transactions and fixed costs constitute a larger fraction of direct health care costs.

Direct non-health care and patient time costs accounted for 58% of the total societal cost of colonoscopy. The higher direct non-health care costs (principally transportation and drivers' time costs) at the VA Medical Center compared to the University Hospital reflect the longer median travel distance and greater drivers' time costs for VA Medical Center patients. Compared to patients at the VA Medical Center, University Hospital patients reported taking more time off from routine activities for their colonoscopies, resulting in higher patient time costs.

This study had several limitations. Study data were obtained from only two hospitals, limiting the generalizability of results. Our study population was small and included only academic medical centers, which may differ significantly from nonacademic or ambulatory care centers. Study size was limited by available resources and the relatively labor-intensive nature of detailed microcosting and time-and-motion studies compared to gross-costing methods. The study exclusion criteria may have created a sample with median costs that differ from those that would be obtained for the whole population undergoing colonoscopy.

While our monetary estimate of colonoscopy cost may have limited generalizability, our microcosting approach demonstrates a method for making highly accurate cost estimates that can be adapted to many different settings. Time-and-motion studies and process analysis provide a framework for comparing colonoscopy cost across institutions that is similarly flexible. Observed variation in transactions and direct non-health care costs suggest that differences in institutional process characteristics may be an important source of cost variation. Our methods could be used in a variety of practice settings to obtain a more generalizable estimate of colonoscopy cost and the processes that determine it.

Our estimates of capacity utilization required measuring the average length of endoscopic procedures other than colonoscopy, which were necessarily less accurate than the values obtained for colonoscopy. Our estimates also assumed that room occupancy was always the rate-limiting factor in provision of a procedure. Our estimates thus represent the lower limits of actual capacity utilization and, by extension, may overestimate direct health care costs.

The cost of colonoscopy is an important variable in determining the cost and cost-effectiveness of colorectal cancer screening. Microcosting and time-and-motion techniques provide accurate cost estimates that can account for all components of colonoscopy cost. Direct non-health care and patient time costs are significant and may impact colorectal cancer screening rates; these costs should be included in all cost estimates that adopt the societal perspective. This study demonstrates both the value of using microcosting methods and the important distinction between societal and institutional perspectives in cost analyses. These findings suggest the need for a multicenter assessment of colonoscopy costs using microcosting and time-and-motion techniques. These techniques could also be adapted to investigate other health care interventions where accurate cost estimates are necessary.

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Conflicts of Interest: *None disclosed.*

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APPENDIX

Additional details of Microcosting and Time-and-Motion Techniques

Resource Identification. Resources consumed during each transaction included all personnel, equipment, and medications associated with performing colonoscopy as well as resources administered outside the endoscopy unit such as overhead (e.g. utilities), building costs, and administrative costs. Resources consumed during particular transactions were measured through real-time observation. The cost of complications associated with colonoscopy was not addressed in this study.

Direct Observation of Resource Utilization. The same nurse physically accompanied every participant during his or her colonoscopy from the patient's leaving the waiting room through his or her postprocedure recovery. Using a watch, this nurse recorded the time that all health care personnel arrived at and left a patient's bedside on a standardized data collection tool that allowed calculation of the total number of minutes that each type of health care personnel (e.g. nurse, resident) spent providing care to each patient. The nurse also directly observed and recorded the medication and equipment used for each procedure.

Using a watch, one author (SGH) personally observed a convenience sample of at least 20 instances of each coordinating transaction at both hospitals and recorded the start and stop times for each coordinating transaction on a standardized data collection instrument that allowed calculation of the mean duration of each coordinating transaction to the nearest minute. For transactions performed by several different types of health care personnel (e.g. nurses and GI technicians), separate sets of observations were made for each personnel type. The mean time required to verify insurance approval at the University Hospital was derived from both observation and interviews with insurance coordinators, who obtained approvals for multiple patients' procedures in batches rather than processing each patient's approval separately.

Monetary Valuation of Resources. To estimate operating utilization, we divided the estimated number of hours spent performing procedures during FY 2002 by the total number of room-hours (number of rooms per procedure unit multiplied by the total hours of operation during FY 2002) at each hospital during FY 2002. One author (SGH) observed a convenience sample of at least 20 of each type of noncolonoscopy endoscopic procedure performed at each hospital to determine mean procedure length. These values and the mean duration for colonoscopy at each site were used to calculate the total number of hours spent performing procedures in FY 2002. The capacity utilization was calculated to be 59% for the University Hospital and 48% for the VA Medical Center. After adjusting the per-minute wages for administrative overhead and capacity utilization (see Table 1 notes), labor costs were calculated by multiplying the employee time for each procedure by the appropriate per-minute rate. For transactions that were conducted by more than one type of health care worker, the per-minute compensation rate used to determine cost was a weighted average based on the fraction of total observed transactions completed by each type of health care worker.

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