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Optimizing Clinical and Economic Outcomes of Surgical Therapy for Patients with Colorectal Cancer and Synchronous Liver Metastases

Daniel E Abbott, MD, Scott B Cantor, PhD, Chung-Yuan Hu, MPH, PhD, Thomas A Aloia, MD, FACS, Y Nancy You, MD, MHSc, FACS, Sa Nguyen, MS, and George J Chang, MD, MS, FACS

Departments of Surgical Oncology (Abbott, Hu, Aloia, You, Nguyen, Chang, Rodriguez-Bigas, Skiber, Feig Curley, Vauthey) and Biostatistics (Cantor), The University of Texas MD Anderson Cancer Center, Houston, TX

Abstract

BACKGROUND—Traditionally, resection for colorectal cancer with resectable synchronous liver metastases was performed separately. However, safety and efficacy of simultaneous resection has been demonstrated in selected patients. The purpose of this study was to evaluate outcomes and economic implications of simultaneous and staged resections.

STUDY DESIGN—We conducted a retrospective cohort study of consecutive colorectal cancer patients with resectable synchronous liver metastases treated between 1993 and 2010, constructing a decision tree comparing simultaneous and staged resections. For generalizability the analysis was conducted from a payer perspective, using costs derived from 2010 Medicare reimbursement. Decision models incorporated the severity-refined DRG complications (CC/MCC) modifiers. Sensitivity analyses used alternative models of DRG reimbursement.

RESULTS—144 patients were analyzed. Sixty (41.7%) underwent simultaneous, and 84 (58.3%) underwent staged resection. Median overall survival did not differ between the simultaneous and the staged cohorts (66.3 vs. 65.6 months, respectively), nor did the overall complication rate (38.3% vs. 40.5%, respectively). Median total length of hospitalization was significantly shorter in the simultaneous cohort (8 vs. 14 days; $p=.001$). In the base model, the simultaneous strategy cost less than the staged strategy (\$20,983 vs. \$25,298 per case)—savings of 17.1%. Sensitivity analyses examining alternative severity-refined DRG reimbursements demonstrated potential cost savings, in all but one extreme sensitivity analysis, ranging from 9.8% to 27.3% favoring simultaneous resection.

CONCLUSIONS—The simultaneous resection strategy was oncologically equivalent and more cost efficient for patients with primary colorectal cancer presenting with resectable liver metastases. A reduction in overall length of hospital stay was an associated benefit. Future studies

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Correspondence address: George J. Chang, MD, M.S., F.A.C.S., F.A.S.C.R.S., Associate Professor, Department of Surgical Oncology, Box 301402, Unit 444, The University of Texas MD Anderson Cancer Center, 1400 Pressler Street, Houston, TX, 77230-1402; phone (713) 563-1875; gchang@mdanderson.org.

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should explore the feasibility and clinical implications of policies to maximize the potential for simultaneous resection in this cohort of patients.

INTRODUCTION

Colorectal cancer presenting with metastasis to the liver is a challenging clinical scenario. Traditionally, colorectal cancer patients with resectable synchronous liver metastases have undergone two separate operations: one to extirpate the primary tumor and one to resect the liver metastasis or metastases. More recently, several institutions have established the safety and feasibility of simultaneous colorectal and hepatic resections.^{1–10} In properly selected patients, simultaneous resections and staged resections have comparable oncologic outcomes, and equivalent—or perhaps fewer—overall complications. If accomplished without increasing morbidity or mortality, the potential benefits of one surgical procedure over two are clear: one hospitalization instead of two; a shorter total duration of inpatient hospital stay; and commitment of fewer financial and human resources.

However, the appropriateness of simultaneous resection remains controversial, and this approach may not be feasible in all hospital systems. Simultaneous resection requires surgeon experience, appropriate intensive care unit expertise, interventional radiology resources, and inpatient processes to ‘rescue’ patients who experience acute deterioration.^{11–15} Thus, appropriate patient selection within a hospital system that is capable of caring for complex and potentially critically ill patients is important to optimizing decisions regarding surgical management of these patients.

In an era of increasing cost consciousness, it is important to examine the fiscal consequences of treating these patients. As health care costs in the United States (US) continue to rise with projection to reach 25% of GDP in 2025, it is appropriate to consider the economic impact of treating these patients in comparative effectiveness research studies to explore ways to improve the efficiency of health care delivery without compromising patient safety, quality of health care delivery, or long-term outcomes.¹⁶

Keeping the nuances of the simultaneous and staged strategies in mind, we hypothesized that a cost-minimized approach that does not compromise surgical outcomes can be determined for treating patients presenting with colorectal cancer metastases to the liver. Although the cost-effectiveness of different treatment strategies has been studied in patients undergoing hepatic metastasectomy for metachronous colorectal cancer metastases in the liver,¹⁷ a cost analysis of surgical treatments for patients with synchronous colorectal cancer metastases in the liver has not been performed. The purpose of this study was to compare the surgical outcomes and estimated payer costs of simultaneous and staged resections of the primary tumor and liver metastases in patients with synchronous disease using standardized Medicare-based reimbursement.

METHODS

Patient selection

Following Institutional Review Board approval, data on patients undergoing colorectal and hepatic resection for colorectal cancer with synchronous metastases to the liver between 1993 and 2010 were reviewed from a secure institutional database at The University of Texas MD Anderson Cancer Center. All patients had undergone both the colorectal and the hepatic resections at MD Anderson Cancer Center. All tumors were resected with curative intent; treatment with radiofrequency ablation was defined as an acceptable treatment modality if resection was not technically feasible (i.e. if the resultant liver remnant would be too low in volume). Patients were excluded if they presented with colorectal cancer

recurrence at the primary site, metachronous hepatic metastases or if complete resection was not performed.

Cost estimates

Cost data were estimated based on Medicare reimbursements in 2010 U.S. dollars. Dollar amounts for procedures categorized by Current Procedural Terminology (CPT) codes and diagnosis-related group (DRG) codes were determined from the Centers for Medicare and Medicaid Services and the Agency for Healthcare Research and Quality, respectively (Table 1).^{18, 19} The DRG based reimbursements were calculated based on cost-to-charge ratios, using national median charges and discharges for specific DRGs. The CPT codes were used to estimate surgeon fees for total proctocolectomy, total abdominal colectomy, partial colectomy, low anterior resection, abdominoperineal resection, minor hepatic resection, hepatic lobectomy, and extended hepatic resection, respectively. Reimbursement for anesthesia services was based on CPT code 840 with increased reimbursement per 15 minutes of anesthesia services. The CPT codes 74170 and 49040 were used for computed tomography and drainage of intra-abdominal abscess, respectively. When applicable, CPT codes included modifiers for technical and professional fees. For DRG coding, a severity-refined DRG system was defined by complicating conditions (CC) and major complicating conditions (MCC) as modifiers for various reimbursements. The DRG codes 329, 330, and 331 were used for major large bowel procedures with MCC, CC, and no complications, respectively. The DRG codes 332, 333, and 334 were used for rectal resections with MCC, CC and no complications respectively. The DRG codes 405, 406, and 407 were used for hepatic resections with MCC, CC, and no complications, respectively. For DRG reimbursements of simultaneous resections, the model in question determined the appropriate reimbursement.

Treatment models and sensitivity analysis

A treatment model (TreeAge Pro 2011; TreeAge Software, Inc., Williamstown, MA) was created as a decision tree with branching nodes to represent the possibilities of simultaneous versus staged resections, major (> 3 segments) versus minor hepatic resections, and one or more complications versus no complications (at either operation for staged resections) (Fig. 1). The base case model was predicated on all simultaneous resections billed using a hepatic CC DRG, with staged resections billed as CC DRG only if a complication occurred. For all models, the costs associated with the treatment of complications (e.g., percutaneous drainage of abscess) were added to the model on the basis of the observed rates of these complications in the cohorts.

Because reimbursement for complications is subject to variation, one-way sensitivity analyses were performed by constructing alternative models of reimbursement based on the absence or presence of the CC and MCC designations (Table 2). The three sensitivity models were as follows: 1) simultaneous procedures were billed at higher levels, with complications billed as MCC while staged procedures were billed at the same level as in the base case and complications were billed as CC; 2) procedures for both cohorts billed at highest possible reimbursement levels (with all complications billed as MCC); and 3) procedures for both cohorts billed at the lowest levels possible, with all complications billed as CC. In the base case scenario, the complication rate in the staged cohort was also altered to identify its potential influence on final cost.

Statistical analysis

Statistical analysis was performed with SPSS version 17.0 software (SPSS Inc., Chicago, IL). Non-parametric variables were described using the median and inter-quartile range (IQR) and compared using the Mann-Whitney test. Categorical variables were compared

using the chi-square tests. Peri-operative mortality was defined as death within 90 days of surgery. Overall survival was calculated from the date of surgery to the date of death. Recurrence-free survival was calculated from the date of surgery to the date of cancer recurrence, either locoregional or systemic, or the date of death from another cause. Cases were censored if the patient was alive at the date of last follow-up. Both the overall and recurrence-free survival were calculated using the Kaplan-Meier method. Univariate analyses were performed using the log-rank test to assess the following variables for their association with overall and recurrence-free survival: surgical strategy (simultaneous vs. staged), sex, body mass index (>30 vs. 30 , kg/m^2), type of colorectal resection, type of liver resection, number of liver metastases, neoadjuvant chemotherapy received, neoadjuvant radiation therapy received, recurrence (for overall survival only), and complication. Multivariable Cox regression analysis with backward stepwise selection was performed to evaluate the association of variables on overall and recurrence-free survival. Final model variables were surgical strategy, body mass index, type of liver resection and number of liver metastases. These variables were chosen based on their significance on univariate analysis and/or their importance in surgical decision making and their potential influence on postoperative morbidity and mortality. A p -value of <0.05 was considered statistically significant, and a hazard ratio greater than 1 indicated decreased survival.

RESULTS

Patient Characteristics and Overall and Recurrence-free Survival

There were 84 patients in the staged resection cohort and 60 in the simultaneous resection cohort. There were no significant differences between cohorts with respect to era of treatment. The median follow-up time was 35.7 months. In the staged and simultaneous cohorts, 5 of 84 (6.0%) and 4 of 60 (6.7%) patients were lost to follow up (i.e. not seen in surveillance within the final year of the study), respectively. Demographic and clinical data are shown in Table 3. Compared with the simultaneous resection cohort, the staged resection cohort was more likely to have undergone a major liver resection (75.0% vs. 33.3%; $p < 0.001$) and to have had more than 5 metastases in the hepatic specimen (32.1% vs. 8.3%; $p < 0.001$). The staged resection cohort had a higher median total estimated blood loss (600 ml [IQR: 450–1000 ml] vs. 325 ml [IQR: 200–600]; $p < 0.001$) and total operating room time (449 minutes [IQR: 339–578 minutes] vs. 305 minutes [IQR: 239–381]; $p < 0.001$). The median total length of hospital stay was longer in the staged resection cohort (14 days [IQR 11–17 days] vs. 8 days [IQR: 7–11 days, $p < 0.001$).

Overall perioperative mortality and complication rates did not differ significantly between resection strategies. The perioperative mortality rates in the simultaneous and staged cohorts were 3.3% and 1.2%, respectively ($p = 0.38$), and the complication rates were 38.3% and 40.5%, respectively. The staged cohort had a significantly higher rate of wound infections (3.3% vs. 11.9%; $p = 0.046$) and a statistically non-significant increase in bile leaks (3.3% vs. 7.1%; $p = 0.30$) than the simultaneous cohort.

The association of the clinical variables in our dataset with recurrence-free and overall survival, based on univariate and multivariate analysis, confirmed a previously reported institutional experience.²⁰ On univariate analysis, the simultaneous and staged resection cohorts had similar median overall survival times of 66.3 months (95% confidence interval [CI]: 38.6–94.0 months) and 65.6 months (95% CI: 44.3–87.0 months), respectively ($p = 0.62$). The median recurrence-free survival times were also similar in the simultaneous and staged resection cohorts, at 18.1 months each (95% CI: 1.1–35.0 months and 15.6–20.7 months, respectively; $p = 0.95$). In multivariable analysis, surgical strategy was not an independent predictor of overall or recurrence-free survival time. For the simultaneous resection cohort, relative to the staged resection cohort, the hazard ratios were 1.3 for

recurrence-free survival (95% CI: 0.62–1.75; $p=0.88$), and 1.4 for overall survival (95% CI 0.74–2.65; $p=0.3$).

Base case cost and sensitivity analysis

The base case scenarios (Table 2) resulted in a mean cost of \$20,983 per patient in the simultaneous resection cohort and \$25,298 per patient in the staged cohort (Fig. 2). The cost difference of \$4,315 represents a 17.1% savings per patient in the simultaneous resection group.

The first alternative model (“maximum reimbursement for simultaneous resection”) maximized reimbursement for the simultaneous cohort and designated all complications as MCC; staged resections were reimbursed as in the base case model (all complications designated as CC). This resulted in a slightly higher per patient cost in the simultaneous resection cohort, of \$2,963, or 10.5%.

The second alternative model (“maximum reimbursement for both strategies”) maximized reimbursement for both simultaneous and staged resections, with all complications for both cohorts designated as MCC. With this model, the simultaneous and staged resection strategies resulted in mean costs of \$28,261 and \$31,382 per patient, respectively, for a savings of \$3,571 (11.2%) for simultaneous resection.

The third alternative model (“minimum reimbursement for both strategies”) minimized payments for both treatment schemes. Reimbursements for the staged cohort in this scenario were the same as in the base case model, while reimbursements for simultaneous resection were designated with either no complications or CC on the basis of observed complications in our patient population. With this paradigm, simultaneous resection still cost substantially less than staged resection at a mean cost of \$17,866 versus \$24,564 per patient, respectively—a savings of \$6,698 (27.3%) per patient.

We also attempted to determine a complication rate threshold at which staged resection would become less costly than simultaneous resection. In this scenario, reimbursement for simultaneous resections was the same as in the base case (all complications as CC) while the complication rate for staged resections were set to be 0. Despite this extreme sensitivity analysis, simultaneous resections remained less costly than staged resections, at a mean of \$20,983 versus \$23,263 per patient, a savings of \$2,280 (9.8%) per patient.

DISCUSSION

In this study, the surgical strategies of simultaneous and staged resections of colorectal cancer and synchronous metastases in the liver were compared using primary patient data. We observed no differences in overall rates of complication, recurrence-free or overall survival between the two strategies. Simultaneous resection, however, was associated with a shorter length of hospital stay, shorter operating room time, and less total estimated blood loss. Simultaneous resection also resulted in lower overall reimbursement costs than staged resection, in all but one extreme model in the sensitivity analysis.

The impact of the shorter total hospital stay with simultaneous resection also includes 1) the benefits to patients, with less time away from home as well as less exposure to hospital pathogens, and 2) the opportunity costs for patients’ families, hospitals, and health care delivery systems that are associated with longer hospital stays (e.g. occupation of hospital beds and nursing staff). These opportunity costs are difficult to measure but may indeed increase the actual cost savings beyond the estimates in this study.

In addition to assessment of clinical outcomes, a major goal of this study was to compare costs associated with alternative strategies of treating colorectal cancer with synchronous metastases to the liver. The base case, comparing simultaneous and staged resection, identified a mean cost savings per patient of \$4,315, or 17.1%, with simultaneous resection. Our base model was constructed to reflect one reasonable reimbursement strategy given the possible permutations. Alternative models were based on billing and reimbursement differences that could result from differing interpretations of the CC and MCC designations by coding professionals. Although the Centers for Medicare and Medicaid Services set forth coding guidelines to better standardize reimbursement for CC and MCC procedures, there are variations in how hospital stays are billed. For example, coders may interrogate a patient's hospital stay and, upon encountering an event that qualifies for CC reimbursement, stop their evaluation of that patient's stay and move on to the next patient. This practice, known as "efficient coding", may ultimately lead to lower reimbursements, as other events in the patient's inpatient course that may have qualified for MCC reimbursement would then be missed.²¹ Given this variation, we performed sensitivity analyses, including both extremes of the simultaneous versus staged cost spectrum. The only scenario in which staged resection became less costly was under the assumption that all complications in the simultaneous cohort were reimbursed with the MCC designation. This finding highlights the significant reimbursement differences between CC and MCC payments (Table 1). Additionally, the likelihood of this reimbursement scheme is extremely low—such one-sided reimbursement for only one of the strategies was included as a hypothetical, but less plausible, reimbursement strategy.

As with all cost analyses one must choose a perspective from which to approach the clinical scenario in question. We chose to perform our evaluation from a societal perspective, using Medicare as a publically funded payer to reflect a common real-life scenario. Furthermore, open access to Medicare reimbursement data allows precise estimation of each level of care, and is widely applicable to a large population of colorectal cancer patients. Additionally, these monetary estimates are a more reliable reflection of the true cost of care than, for example, hospital charges. These latter figures are institution- and market dependent and frequently do not approximate payer reimbursement (i.e., what individuals ultimately pay through insurance premiums and taxes).

We recognize that this strategy is an imperfect method of capturing costs incurred by all patients. A significant percentage of patients with synchronous colorectal cancer metastases to the liver are not covered by Medicare, and the estimated reimbursement amounts we used in this study are almost certainly lower than what private insurer reimbursements actually are; so our absolute dollar figures may be falsely low for these reasons. However, we do not expect that the percentage differences between our findings and private payer reimbursement are dramatically different. Therefore, the range of potential cost savings is anticipated to be generalizable to other payer sources. In fact, it is possible that if all payer types were considered, the absolute dollar amount saved by a policy of using simultaneous resection of primary colorectal tumors and synchronous metastases in the liver could be higher than what is reported here.

This study is subject to biases associated with any non-randomized, retrospective comparative cohort study. As noted in Table 3, patients with >5 hepatic metastases and those undergoing major liver resections were significantly more likely to have staged procedures. Because of their extent of disease, these patients may not have been eligible for simultaneous resection. Our data suggested that simultaneous resection is safe and appropriate for all patients for whom extent of resection for primary and metastatic lesions does not entail prohibitive risk, and despite some differences between the study cohorts, simultaneous resection is preferred when feasible. While always incorporating patient

functional status prominently in our surgical decision making, we generally perform simultaneous hepatic and colorectal resections if 1) only a minor hepatectomy is required, regardless of colon or rectal primary site or 2) a major hepatectomy is required with a colon (not rectal) resection. All other clinical scenarios tend to be managed with staged resection. One may argue that these results are not generalizable to all centers, which may be true. Thus, in addressing these complex clinical scenarios, future efforts should focus on improving hospital resources and capabilities to accommodate these patients, or increasing referral to centers with available expertise and resources.

The use of payer reimbursement data also may not take into account the actual costs incurred during the care of a patient. However, this is a well established method for comparative economic analyses.^{22, 23} In addition, this practice avoids data skewing by outlier patients that would occur if actual costs could be captured. These potential limitations were yet further rationale to perform sensitivity analyses considering the extremes of clinical scenarios. Additionally, we did not include outpatient costs such as home health care or rehabilitation services. We did not include these data in the analyses because 1) the type, extent, and costs of these resources can vary markedly, subjecting the model to undue influence by cost outliers, and 2) our focus was on inpatient treatment costs. If such costs were included, however, we suspect that the analysis would more firmly support the simultaneous approach, as this cohort had fewer surgical site infections.

In summary, these data demonstrate that simultaneous resection for colorectal cancer and synchronous liver metastases has a similar morbidity profile to that of staged resection but costs substantially less per patient. The shorter total hospital stay in the simultaneous resection cohort is an added benefit to both the patient and the provider. Because their recurrence-free and overall survival rates were similar, these data suggest that simultaneous resection for colorectal cancer and synchronous liver metastases be performed when safe and feasible. Further study of the health care delivery processes that improve access to simultaneous resection for synchronous metastatic colorectal cancer at presentation should be pursued. As fiscal concerns become a more prominent component of medical decision making, these systemic changes represent an important opportunity to improve the efficiency of health care resource utilization.

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ABBREVIATIONS

CRC	Colorectal cancer
CEA	Carcinoembryonic antigen
BMI	body mass index
CPT	Current Procedural Terminology
DRG	diagnosis-related group
CC	complicating condition

MCC	major complicating condition
OR	operating room
CT	computed tomography

REFERENCES

1. Chua HK, Sondenaa K, Tsiotos GG, et al. Concurrent vs. staged colectomy and hepatectomy for primary colorectal cancer with synchronous hepatic metastases. *Dis Colon Rectum*. 2004; 47:1310–1316. [PubMed: 15484344]
2. Doko M, Zovak M, Ledinsky M, et al. Safety of simultaneous resections of colorectal cancer and liver metastases. *Coll Antropol*. 2000; 24:381–390. [PubMed: 11216406]
3. Elias D, Detroz B, Lasser P, Plaud B, Jerbi G. Is simultaneous hepatectomy and intestinal anastomosis safe. *Am J Surg*. 1995; 169:254–260. [PubMed: 7840389]
4. Lyass S, Zamir G, Matot I, et al. Combined colon and hepatic resection for synchronous colorectal liver metastases. *J Surg Oncol*. 2001; 78:17–21. [PubMed: 11519063]
5. Martin R, Paty P, Fong Y, et al. Simultaneous liver and colorectal resections are safe for synchronous colorectal liver metastasis. *J Am Coll Surg*. 2003; 197:233–241. discussion 241–242. [PubMed: 12892803]
6. Tanaka K, Shimada H, Matsuo K, et al. Outcome after simultaneous colorectal and hepatic resection for colorectal cancer with synchronous metastases. *Surgery*. 2004; 136:650–659. [PubMed: 15349115]
7. Vogt P, Raab R, Ringe B, Pichlmayr R. Resection of synchronous liver metastases from colorectal cancer. *World J Surg*. 1991; 15:62–67. [PubMed: 1994607]
8. Weber JC, Bachellier P, Oussoultzoglou E, Jaeck D. Simultaneous resection of colorectal primary tumour and synchronous liver metastases. *Br J Surg*. 2003; 90:956–962. [PubMed: 12905548]
9. Martin RC 2nd, Augenstein V, Reuter NP, et al. Simultaneous versus staged resection for synchronous colorectal cancer liver metastases. *J Am Coll Surg*. 2009; 208:842–850. discussion 850–852. [PubMed: 19476847]
10. Reddy SK, Pawlik TM, Zorzi D, et al. Simultaneous resections of colorectal cancer and synchronous liver metastases: a multi-institutional analysis. *Ann Surg Oncol*. 2007; 14:3481–3491. [PubMed: 17805933]
11. Cowan JA Jr, Dimick JB, Thompson BG, et al. Surgeon volume as an indicator of outcomes after carotid endarterectomy: an effect independent of specialty practice and hospital volume. *J Am Coll Surg*. 2002; 195:814–821. [PubMed: 12495314]
12. Birkmeyer JD, Stukel TA, Siewers AE, et al. Surgeon volume and operative mortality in the United States. *N Engl J Med*. 2003; 349:2117–2127. [PubMed: 14645640]
13. Young MP, Goode VJ, McBride K, James B, Fisher ES. Inpatient transfers to the intensive care unit: delays are associated with increased mortality and morbidity. *J Gen Intern Med*. 2003; 18:77–83. [PubMed: 12542581]
14. Ghaferi AA, Osborne NH, Birkmeyer JD, Dimick JB. Hospital characteristics associated with failure to rescue from complications after pancreatectomy. *J Am Coll Surg*. 2010; 211:325–330. [PubMed: 20800188]
15. Friesen CR, Earle CC, Silber JH, Aiken LH. Hospital characteristics, clinical severity, and outcomes for surgical oncology patients. *Surgery*. 2010; 147:602–609. [PubMed: 20403513]
16. Munoz E, Munoz W 3rd, Wise L. National and surgical health care expenditures, 2005–2025. *Ann Surg*. 251:195–200. [PubMed: 20054269]
17. Gazelle GS, Hunink MG, Kuntz KM, et al. Cost-effectiveness of hepatic metastasectomy in patients with metastatic colorectal carcinoma: a state-transition Monte Carlo decision analysis. *Ann Surg*. 2003; 237:544–555. [PubMed: 12677152]
18. US Department of Health and Human Services. [Accessed October 16, 2011] Centers for Medicare and Medicaid Services. <http://www.cms.gov>.

19. US Department of Health and Human Services. [Accessed October 16, 2011] HCUPnet. <http://hcupnet.ahrq.gov/HCUPnet.jsp>.
20. Brouquet A, Mortenson MM, Vauthey JN, et al. Surgical strategies for synchronous colorectal liver metastases in 156 consecutive patients: classic, combined or reverse strategy. *J Am Coll Surg*. 2010; 210:934–941. [PubMed: 20510802]
21. Wynn BO, Beckett MK, Hilborne LH, et al. RAND Health. Evaluation of Severity-adjusted DRG Systems. http://www.rand.org/pubs/working_papers/WR434.html. Published March 2007.
22. Huang ES, Gazelle GS, Hur C. Consensus guidelines in the management of branch duct intraductal papillary mucinous neoplasm: a cost-effectiveness analysis. *Dig Dis Sci*. 2010; 55:852–860. [PubMed: 19834805]
23. Zanooco K, Angelos P, Sturgeon C. Cost-effectiveness analysis of parathyroidectomy for asymptomatic primary hyperparathyroidism. *Surgery*. 2006; 140:874–881. discussion 881–882. [PubMed: 17188133]

Figure 1.
Decision tree for comparison of cost modeling strategies. CRC, colorectal cancer.

Percent cost savings

Figure 2.

Base case and sensitivity analysis based on reimbursements for various diagnosis-related groups. Green bar, absolute cost savings; red bar, staged; blue bar, simultaneous.

Table 1

Reimbursements by Current Procedural Terminology and Diagnosis-Related Group Codes

Procedure	Code	Reimbursement, 2010 U.S. dollars
CPT		
Total proctocolectomy	44155	2076.51
Total abdominal colectomy	44150	1867.44
Partial colectomy	44140	1347.36
Low anterior resection	45111	1092.05
Abdominoperineal resection	45110	1854.33
		150.29+21.47 per each additional 15
Anesthesia fee	840	min
Partial hepatic lobectomy	47120	2337.88
Hepatic lobectomy	47125/47130	3210.40
Extended hepatic resection	47122	3459.11
CT for complication	74170	402.26
Drainage for intra-abdominal fluid collection	49040	1004.33
DRG		
Colon resection		
Without CC	331	7,245
With CC	330	12,456
With MCC	329	27,890
Rectal resection		
Without CC	334	7,533
With CC	333	11,736
With MCC	332	24,596
Liver resection		
Without CC	407	10,668
With CC	406	16,278
With MCC	405	35,128

CC, complicating condition; CPT, Current Procedural Terminology; DRG, diagnosis related group; MCC, major complicating condition.

Table 2

Reimbursement Schedule for Sensitivity Analyses

Model	Simultaneous resection *	Staged resection
Base Case	CC	Any complication as CC
Maximum reimbursement for simultaneous resection	CC, any complication as MCC	Any complication as CC
Maximum reimbursement for both strategies	CC, any complication as MCC	Any complication as MCC
Minimum reimbursement for both strategies	Base rate billing, any complication as CC	Base rate billing, any complication as CC

* Simultaneous resection billed as CC due to comorbid condition of additional tumor resection.
 CC, complicating condition; CPT, Current Procedural Terminology; DRG, diagnosis-related group; MCC, major complicating condition.

Table 3

Demographic and Clinicopathologic Features of Simultaneous and Staged Resection Cohorts (n=144)

Variable	n (%)		P Value
	Simultaneous	Staged	
Total	60	84	--
Median age (IQR), years	57.5 (45.5–63.9)	53.3 (45.5–60.8)	0.16
Sex			0.31
Male	40 (66.7)	49 (58.3)	
Female	20 (33.3)	35 (41.7)	
ASA Class			0.09
2	28 (46.7)	51 (60.7)	
3	32 (53.3)	33 (39.3)	
Median body mass index (IQR)	27.9 (24.2–29.8) kg/m ²	28.4 (24.6–31.2) kg/m ²	0.62
Type of CRC resection			0.44
Colon	26 (43.3)	31 (36.9)	
Rectal	34 (56.7)	53 (63.1)	
Transfused at CRC surgery			0.91
Yes	12 (20)	15 (17.9)	
No	48 (80)	69 (82.1)	
Type of liver resection			<0.001
Minor (<3 segments)	40 (66.7)	21 (25)	
Major (≥ 3 segments)	20 (33.3)	63 (75)	
Transfusion at liver surgery			--
Yes	--	11 (13.1)	
No	--	73 (86.9)	
Median total EBL (IQR)	325 (200–600) ml	600 (450–1000) ml	<0.001
Median total OR time (IQR)	305 (239–381) min	449 (339–578) min	<0.001
Location of CRC tumor			0.59
Right	12 (20)	10 (11.9)	
Transverse	1 (1.7)	2 (2.4)	
Left	5 (8.3)	5 (6)	
Sigmoid	11 (18.3)	15 (17.9)	
Rectum	27 (45)	40 (47.6)	
Rectosigmoid	4 (6.7)	12 (14.3)	
Ostomy at CRC resection			0.69
Yes	23 (38.3)	36 (42.9)	
No	37 (61.7)	48 (57.1)	
Perioperative death			0.38
Yes	2 (3.3)	1 (1.2)	
No	58 (96.7)	83 (98.8)	
T stage of primary			0.04
CR	2 (3.3)	0 (0)	

Variable	n (%)		P Value
	Simultaneous	Staged	
1	0 (0)	1 (1.2)	
2	8 (13.3)	8 (9.5)	
3	49 (81.7)	63 (75)	
4	1 (1.7)	12 (14.3)	
N stage of primary			0.7
0	17 (28.3)	24 (28.6)	
1	20 (33.3)	33 (39.3)	
2	23 (38.3)	27 (32.1)	
Grade of primary (differentiation)			0.66
Well to moderate	1 (1.7)	0 (0)	
Moderately	47 (78.3)	71 (84.5)	
Moderate to poor	6 (10)	8 (9.5)	
Poorly	4 (6.7)	4 (4.8)	
Unknown	2 (3.3)	1 (1.2)	
No. of liver metastases			<0.001
5	55 (91.7)	57 (67.9)	
>5	5 (8.3)	27 (32.1)	
Median CEA level (IQR)	3.4 (1.6–11.7) ng/ml	9.0 (3.1–51.5) ng/ml	0.012
Preoperative chemotherapy			0.06
Yes	46 (76.7)	52 (61.9)	
No	14 (23.3)	32 (38.1)	
Pre-operative radiation therapy			0.6
Yes	21 (35)	33 (39.3)	
No	39 (65)	51 (60.7)	
Site of recurrence			0.26
Colon or rectum	2 (3.3)	5 (6)	
Liver	24 (40)	31 (36.9)	
Distant	19 (31.7)	29 (34.5)	
None	27 (45)	27 (32.1)	
Complications			
Anastomotic leak	3 (5)	3 (3.6)	0.68
Bile leak	2 (3.3)	6 (7.1)	0.30
Wound infection	2 (3.3)	10 (11.9)	<0.046
Fistula	2 (3.3)	2 (2.4)	0.74
Intra-abdominal abscess	2 (3.3)	1 (1.2)	0.42
Thrombotic	1 (1.7)	1 (1.2)	0.82
Cardiac	3 (5)	4 (4.8)	0.95
Pulmonary	2 (3.3)	3 (3.6)	0.94
Other	6 (10)	4 (4.8)	0.25
None	37 (61.7)	50 (59.5)	

Variable	n (%)		P Value
	Simultaneous	Staged	
Median total LOS (IQR)	8 (7–11) days	14 (11–17) days	<0.001

ASA, American Society of Anesthesiologists; CEA, carcinoembryonic antigen; CRC, colorectal cancer; EBL, estimated blood loss; IQR, interquartile range; LOS, length of stay; OR, operating room.