

CHOOSING WISELY<sup>®</sup>: NEXT STEPS IN IMPROVING HEALTHCARE VALUE

## Impact of Price Display on Provider Ordering: A Systematic Review

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**BACKGROUND:** Displaying order prices to physicians is 1 potential strategy to reduce unnecessary health expenditures, but its impact on patterns of care is unclear.

**OBJECTIVE:** To review characteristics of previous price display interventions, impact on order costs and volume, effects on patient safety, acceptability to physicians, and the quality of this evidence.

**DESIGN:** Systematic review of studies that showed numeric prices of laboratory tests, imaging studies, or medications to providers in real time during the ordering process and evaluated the impact on provider ordering. Two investigators independently extracted data for each study and evaluated study quality using a modified Downs and Black checklist.

**RESULTS:** Of 1494 studies reviewed, 19 met inclusion criteria, including 5 randomized trials, 13 pre-post intervention studies, and 1 time series analysis. Studies were published

between 1983 and 2014. Of 15 studies reporting the quantitative impact of price display on aggregate order costs or volume, 10 demonstrated a statistically significant decrease in the intervention group. Price display was found to decrease aggregate order costs (9 of 13 studies) more frequently than order volume (3 of 8 studies). Patient safety was evaluated in 5 studies and was unaffected by price display. Provider acceptability tended to be positive, although evidence was limited. Study quality was mixed, with checklist scores ranging from 5/21 to 20/21.

**CONCLUSIONS:** Provider price display likely reduces order costs to a modest degree. Patient safety appeared unchanged, though evidence was limited. More high-quality evidence is needed to confirm these findings within a modern context. *Journal of Hospital Medicine* 2016;11:65–76. © 2015 Society of Hospital Medicine

Rising healthcare spending has garnered significant public attention, and is considered a threat to other national priorities. Up to one-third of national health expenditures are wasteful, the largest fraction generated through unnecessary services that could be substituted for less-costly alternatives or omitted altogether.<sup>1</sup> Physicians play a central role in health spending, as they “purchase” nearly all tests and therapies on behalf of patients.

One strategy to enhance cost-conscious physician ordering is to increase transparency of cost data for providers.<sup>2–4</sup> Although physicians consider price an important factor in ordering decisions, they have difficulty estimating costs accurately or finding price information easily.<sup>5,6</sup> Improving physicians’ knowledge of order costs may prompt them to forego diagnostic tests or therapies of low utility, or shift ordering to lower-cost alternatives. Real-time price display during provider order entry is 1 approach for achieving this goal. Modern electronic health records (EHRs) with

computerized physician order entry (CPOE) make price display not only practical but also scalable. Integrating price display into clinical workflow, however, can be challenging, and there remains lack of clarity about potential risks and benefits. The dissemination of real-time CPOE price display, therefore, requires an understanding of its impact on clinical care.

Over the past 3 decades, several studies in the medical literature have evaluated the effect of price display on physician ordering behavior. To date, however, there has been only 1 narrative review of this literature, which did not include several recent studies on the topic or formally address study quality and physician acceptance of price display modules.<sup>7</sup> Therefore, to help inform healthcare leaders, technology innovators, and policy makers, we conducted a systematic review to address 4 key questions: (1) What are the characteristics of interventions that have displayed order prices to physicians in the context of actual practice? (2) To what degree does real-time display of order prices impact order costs and order volume? (3) Does price display impact patient safety outcomes, and is it acceptable to providers? (4) What is the quality of the current literature on this topic?

## METHODS

### Data Sources

We searched 2 electronic databases, MEDLINE and Embase, using a combination of controlled vocabulary terms and keywords that covered both the targeted intervention (eg, fees and charges) and the outcome of

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interest (eg, physician's practice patterns), limited to English language articles with no restriction on country or year of publication (see Supporting Information, Appendix 1, in the online version of this article). The search was run through August 2014. Results from both database searches were combined and duplicates eliminated. We also ran a MEDLINE keyword search on titles and abstracts of articles from 2014 that were not yet indexed. A medical librarian was involved in all aspects of the search process.<sup>8</sup>

### Study Selection

Studies were included if they evaluated the effect of displaying actual order prices to providers during the ordering process and reported the impact on provider ordering practices. Reports in any clinical context and with any study design were included. To assess most accurately the effect of price display on real-life ordering and patient outcomes, studies were excluded if: (1) they were review articles, commentaries, or editorials; (2) they did not show order prices to providers; (3) the context was a simulation; (4) the prices displayed were relative (eg, \$/\$/\$/\$) or were only cumulative; (5) prices were not presented real-time during the ordering process; or (6) the primary outcome was neither order costs nor order volume. We decided a priori to exclude simulations because these may not accurately reflect provider behavior when treating real patients, and to exclude studies showing relative prices due to concerns that it is a less significant price transparency intervention and that providers may interpret relative prices differently from actual prices.

Two reviewers, both physicians and health service researchers (M.T.S. and T.R.B.), separately reviewed the full list of titles and abstracts. For studies that potentially met inclusion criteria, full articles were obtained and were independently read for inclusion in the final review. The references of all included studies were searched manually, and the Scopus database was used to search all studies that cited the included studies. We also searched the references of relevant literature reviews.<sup>9-11</sup> Articles of interest discovered through manual search were then subjected to the same process.

### Data Extraction and Quality Assessment

Two reviewers (M.T.S. and T.R.B.) independently performed data extraction using a standardized spreadsheet. Discrepancies were resolved by reviewer consensus. Extracted study characteristics included study design and duration, clinical setting, study size, type of orders involved, characteristics of price display intervention and control, and type of outcome. Findings regarding patient safety and provider acceptability were also extracted when available.

Study quality was independently evaluated and scored by both reviewers using the Downs and Black

checklist, designed to assess quality of both randomized and nonrandomized studies.<sup>12</sup> The checklist contains 5 items pertaining to allocation concealment, blinding, or follow-up that are not applicable to an administrative intervention like price display, so these questions were excluded. Additionally, few studies calculated sample size or reported post hoc statistical power, so we also excluded this question, leaving a modified 21-item checklist. We also assessed each study for sources of bias that were not already assessed by the Downs and Black checklist, including contamination between study groups, confounding of results, and incomplete intervention or data collection.

### Data Synthesis

Data are reported in tabular form for all included studies. Due to heterogeneity of study designs and outcome measures, data from the studies were not pooled quantitatively. This review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.

## RESULTS

Database searches yielded a total of 1400 articles, of which 18 were selected on the basis of title and abstract for detailed assessment. Reference searching led us to retrieve 94 further studies of possible interest, of which 23 were selected on the basis of abstract for detailed assessment. Thus, 41 publications underwent full manuscript review, 19 of which met all inclusion criteria (see Supporting Information, Appendix 2, in the online version of this article).<sup>13-31</sup> These studies were published between 1983 and 2014, and were conducted primarily in the United States.

### Study Characteristics

There was considerable heterogeneity among the 19 studies with regard to design, setting, and scope (Table 1). There were 5 randomized trials, for which the units of randomization were patient (1), provider team (2), and test (2). There were 13 pre-post intervention studies, 5 of which used a concomitant control group, and 2 of which included a washout period. There was 1 interrupted time series study. Studies were conducted within inpatient hospital floors (8), outpatient clinics (4), emergency departments (ED) or urgent care facilities (4), and hospital operating rooms (3).

Prices were displayed for laboratory tests (12 studies), imaging tests (8 studies), and medications (7 studies). Study scope ranged from examining a single medication class to evaluating all inpatient orders. The type of price used for the display varied, with the most common being the facility charges or "chargemaster prices" (6 studies), and Medicare prices (3 studies). In several cases, price display was only 1 component of the study, and 6 studies introduced additional interventions concurrent with price display, such as cost-effective ordering menus,<sup>29</sup> medication

**TABLE 1. Study Characteristics**

Study	Design	Clinical Setting	Providers	Intervention and Duration	Order(s) Studied	Type of Price Displayed	Concurrent Interventions
Fang et al. <sup>14</sup> 2014	Pre-post study with control group	Academic hospital (USA)	All inpatient ordering providers	CPOE system with prices displayed for reference lab tests; 8 months	All send-out lab tests	Charge from send-out laboratory, displayed as range (eg, \$100–300)	Display also contained expected lab turnaround time
Nougouon et al. <sup>13</sup> 2014	Pre-post study with washout	Academic adult emergency department (Belgium)	9 ED house staff	CPOE system with prices displayed on common orders form, and price list displayed above all workstations and in patient rooms; 2 months	Common lab and imaging tests	Reference costs from Belgian National Institute for Health Insurance and Invalidity	None
Durand et al. <sup>17</sup> 2013	RCT (randomized by test)	Academic hospital, all inpatients (USA)	All inpatient ordering providers	CPOE system with prices displayed; 6 months	10 common imaging tests	Medicare allowable fee	None
Feldman et al. <sup>16</sup> 2013	RCT (randomized by test)	Academic hospital, all inpatients (USA)	All inpatient ordering providers	CPOE system with prices displayed; 6 months	61 lab tests	Medicare allowable fee	None
Horn et al. <sup>15</sup> 2014	Interrupted time series study with control group	Private outpatient group practice alliance (USA)	215 primary care physicians	CPOE system with prices displayed; 6 months	27 lab tests	Medicare allowable fee, displayed as narrow range (eg, \$5–\$10)	None
Ellermdin et al. <sup>18</sup> 2011	Pre-post study with control group	Academic hospital, internal medicine units (South Africa)	Internal medicine physicians (number NR)	Sheet with lab test costs given to intervention group physicians who were required to write out cost for each order; 4 months	Common lab tests	Not reported	None
Schilling <sup>19</sup> 2010	Pre-post study with control group	Academic adult emergency department (Sweden)	All internal medicine physicians in ED	Standard provider workstations with price lists posted on each; 2 months	91 common lab tests, 39 common imaging tests	Not reported	None
Guterman et al. <sup>21</sup> 2002	Pre-post study	Academic-affiliated urgent care clinic (USA)	51 attendings and housestaff	Preformatted paper prescription form with medication prices displayed; 2 weeks	2 H <sub>2</sub> -blocker medications	Acquisition cost of medication plus fill fee	None
Seguin et al. <sup>20</sup> 2002	Pre-post study	Academic surgical intensive care unit (France)	All intensive care unit physicians	Paper quick-order checklist with prices displayed; 2 months	6 common lab tests, 1 imaging test	Not reported	None
Hampers et al. <sup>23</sup> 1999	Pre-post study with washout	Academic pediatric emergency department (USA)	Pediatric ED attendings and housestaff (number NR)	Paper common-order checklist with prices displayed; 3 months	22 common lab and imaging tests	Chargemaster price*	Physicians required to calculate total charges for diagnostic workup
Ornstein et al. <sup>22</sup> 1999	Pre-post study	Academic family medicine outpatient clinic (USA)	46 attendings and housestaff	Microcomputer CPOE system with medication prices displayed; 6 months	All medications	AWP for total supply (acute medications) or 30-day supply (chronic medications)	Additional keystroke produced list of less costly alternative medications
Lin et al. <sup>25</sup> 1998	Pre-post study	Academic hospital operating rooms (USA)	All anesthesia providers	Standard muscle relaxant drug vials with price stickers displayed; 12 months	All muscle relaxant medications	Not reported	None

**TABLE 1. Continued**

Study	Design	Clinical Setting	Providers	Intervention and Duration	Order(s) Studied	Type of Price Displayed	Concurrent Interventions
McLitt et al. <sup>24</sup> 1998	Pre-post study	Academic hospital operating rooms (USA)	90 anesthesia attendings, housestaff and anesthesiologists	List of drug costs displayed in operating rooms, anesthesia lounge, and anesthesia satellite pharmacy; 10 months	22 common anesthesia medications	Hospital acquisition cost	Regular anesthesia department reviews of drug usage and cost
Bates et al. <sup>27</sup> 1997	RCT (randomized by patient)	Academic hospital, medical and surgical inpatients (USA)	All inpatient ordering providers	CPOE system with display of test price and running total of prices for the ordering session; 4 months (lab) and 7 months (imaging)	All lab tests, 35 common imaging tests	Chargemaster price	None
Vedstedt et al. <sup>26</sup> 1997	Pre-post study with control group	Outpatient general practices (Denmark)	231 general practitioners	In practices already using APEX CPOE system, introduction of medication price display (control practices used non-APEX computer system or paper-based prescribing); 12 months	All medications	Chargemaster price	Medication price comparison module (stars indicated availability of cheaper option)
Horrow et al. <sup>28</sup> 1994	Pre-post study	Private tertiary care hospital operating rooms (USA)	56 anesthesia attendings, housestaff and anesthesiologists	Standard anesthesia drug vials and syringes with supermarket price stickers displayed; 3 months	13 neuromuscular relaxant and sedative-hypnotic medications	Hospital acquisition cost	None
Tierney et al. <sup>29</sup> 1993	Cluster RCT (randomized by provider team)	Public hospital, internal medicine services (USA)	68 teams of internal medicine attendings and housestaff	Microcomputer CPOE system with prices displayed (control group used written order sheets); 17 months	All orders	Chargemaster price	CPOE system listed cost-effective tests for common problems and displayed reasonable test intervals
Tierney et al. <sup>30</sup> 1990	Cluster RCT (randomized by clinic session)	Academic, outpatient, general medicine practice (USA)	121 internal medicine attendings and housestaff	Microcomputer CPOE system with pop-up window displaying price for current test and running total of cumulative test prices for current visit; 6 months	All lab and imaging tests	Chargemaster price	None
Everett et al. <sup>31</sup> 1983	Pre-post study with control group	Academic hospital, general internal medicine wards (USA)	Internal medicine attendings and housestaff (number NR)	Written order sheet with adjacent sheet of lab test prices; 3 months	Common lab tests	Chargemaster price	None

NOTE: Abbreviations: AWP, average wholesale price; CPOE, computerized physician order entry; RCT, randomized controlled trial; NR, not reported. "Chargemaster price" is listed when study displayed the facility charge for orders.

**TABLE 2. Study Findings**

Study	No. of Encounters	Primary Outcome Measure(s)	Impact on Order Costs			Impact on Order Volume			Relative Change
			Control Group Outcome	Intervention Group Outcome	Relative Change	Control Group Outcome	Intervention Group Outcome	Relative Change	
Fang et al. <sup>14</sup> 2014	378,890 patient-days	Reference lab orders per 1000 patient-days	NR	NR	NA	51 orders/1000 patient-days	38 orders/1000 patient-days	-25.5% orders/1000 patient-days ( $P < 0.001$ )	
Nougon et al. <sup>19</sup> 2015	2422 ED visits (excluding washout)	Lab and imaging test costs per ED visit	€7.1/visit (lab); €21.8/visit (imaging)	€6.4/visit (lab); €14.4/visit (imaging)	-10.7% lab costs/visit ( $P = 0.02$ ); -33.7% imaging costs/visit ( $P < 0.001$ )	NR	NR	NA	
Durand et al. <sup>17</sup> 2013	NR	Imaging orders compared to baseline 1 year prior	NR	NR	NA	-3.0% total orders	+2.8% total orders	+5.8% total orders ( $P = 0.10$ )	
Feldman et al. <sup>16</sup> 2013	245,758 patient-days	Lab orders and fees per patient-day compared to baseline 1 year prior	+2.9% fees/ patient-day	-9.6% fees/ patient-day	-12.5% fees/patient-day ( $P < 0.001$ )	+5.6% orders/patient-day	-8.6% orders/ patient-day	-14.2% orders/ patient-day ( $P < 0.001$ )	
Horn et al. <sup>15</sup> 2014	NR	Lab test volume per patient visit, by individual lab test	NR	NR	NA	Aggregate data not reported	Aggregate data not reported	5 of 27 tests had significant reduction in ordering (-2.1% to -15.2%/patient visit)	
Eliendin et al. <sup>18</sup> 2011	897 admissions	Lab cost per hospital day	R442.90/day	R284.14/day	-35.8% lab costs/ patient-day ( $P = 0.001$ )	NR	NR	NA	
Schilling <sup>19</sup> 2010	3222 ED visits	Combined lab and imaging test costs per ED visit	€108/visit	€88/visit	-18.8% test costs/visit ( $P = 0.07$ )	NR	NR	NA	
Guterman et al. <sup>21</sup> 2002	168 urgent care visits	Percent of acid reducer prescriptions for ranitidine (the higher-cost option)	NR	NR	NA	49% ranitidine	21% ranitidine	-57.1% ranitidine ( $P = 0.007$ )	
Seguin et al. <sup>20</sup> 2002	287 SICU admissions	Tests ordered per admission; test costs per admission	€341/admission	€266/admission	-22.0% test costs/admission ( $P < 0.05$ )	13.6 tests/admission	11.1 tests/admission	-18.4% tests/admission ( $P = 0.12$ )	
Hampers et al. <sup>23</sup> 1999	4881 ED visits (excluding washout)	Adjusted mean test charges per patient visit	\$86.79/visit	\$63.74/visit	-26.6% test charges/visit ( $P < 0.01$ )	NR	NR	NA	
Ornstein et al. <sup>22</sup> 1999	30,461 outpatient visits	Prescriptions per visit; prescription cost per visit; cost per prescription	\$12.49/visit; \$21.83/prescription	\$13.03/visit; \$22.03/prescription	+4.3% prescription cost/visit ( $P = 0.12$ ); +0.9% cost/prescription ( $P = 0.61$ )	0.66 prescriptions/visit	0.64 prescriptions/visit	-3.0% prescriptions/visit (P value not reported)	
Lin et al. <sup>25</sup> 1998	40,747 surgical cases	Annual spending on muscle relaxants medication	\$378,234/year (20,389 cases)	\$330,923/year (20,358 cases)	-12.5%	NR	NR	NA	

**TABLE 2. Continued**

Study	No. of Encounters	Primary Outcome Measure(s)	Impact on Order Costs			Impact on Order Volume			Relative Change
			Control Group Outcome	Intervention Group Outcome	Relative Change	Control Group Outcome	Intervention Group Outcome	Relative Change	
McLitt et al. <sup>24</sup> 1998	15,130 surgical cases	Anesthesia drug cost per case	\$51.02/case	\$18.99/case	-62.8% drug costs/case (P < 0.05)	NR	NR	NA	
Bates et al. <sup>27</sup> 1997	7090 admissions (lab); 17,381 admissions (imaging)	Tests ordered per admission; charges for tests ordered per admission	\$771/admission (lab); \$276/admission (imaging)	\$739/admission (lab); \$275/admission (imaging)	-4.2% lab charges/admission (P = 0.97); -0.4% imaging charges/admission (P = 0.10)	26.8 lab tests/admission; 1.76 imaging tests/admission	25.6 lab tests/admission; 1.76 imaging tests/admission	-4.5% lab tests/admission (P = 0.74); 0% imaging tests/admission (P = 0.13)	
Vedstedt et al. <sup>26</sup> 1997	NR	Prescribed daily doses per 1000 insured; total drug reimbursement per 1000 insured; reimbursement per daily dose	Reported graphically only	Reported graphically only	"No difference"	Reported graphically only	Reported graphically only	"No difference"	
Horrow et al. <sup>29</sup> 1994	NR	Anesthetic drugs used per week; anesthetic drug cost per week	\$3837/week	\$3179/week	-17.1% drug costs/week (P = 0.04)	97 drugs/week	94 drugs/week	-3.1% drugs/week (P = 0.56)	
Tierney et al. <sup>29</sup> 1993	5219 admissions	Total charges per admission	\$6964/admission	\$6071/admission	-12.7% total charges/admission (P = 0.02)	NR	NR	NA	
Tierney et al. <sup>30</sup> 1990	15,257 outpatient visits	Test orders per outpatient visit; test charges per outpatient visit	\$51.81/visit	\$45.13/visit	-12.9% test charges/visit (P < 0.05)	1.82 tests/visit	1.56 tests/visit	-14.3% tests/visit (P < 0.005)	
Everett et al. <sup>31</sup> 1983	NR	Lab tests per admission; charges per admission	NR	NR	NA	NR	NR	"No statistically significant changes"	

NOTE: Abbreviations: ED, emergency department; NA, not applicable; NR, not reported; SICU, surgical intensive care unit.

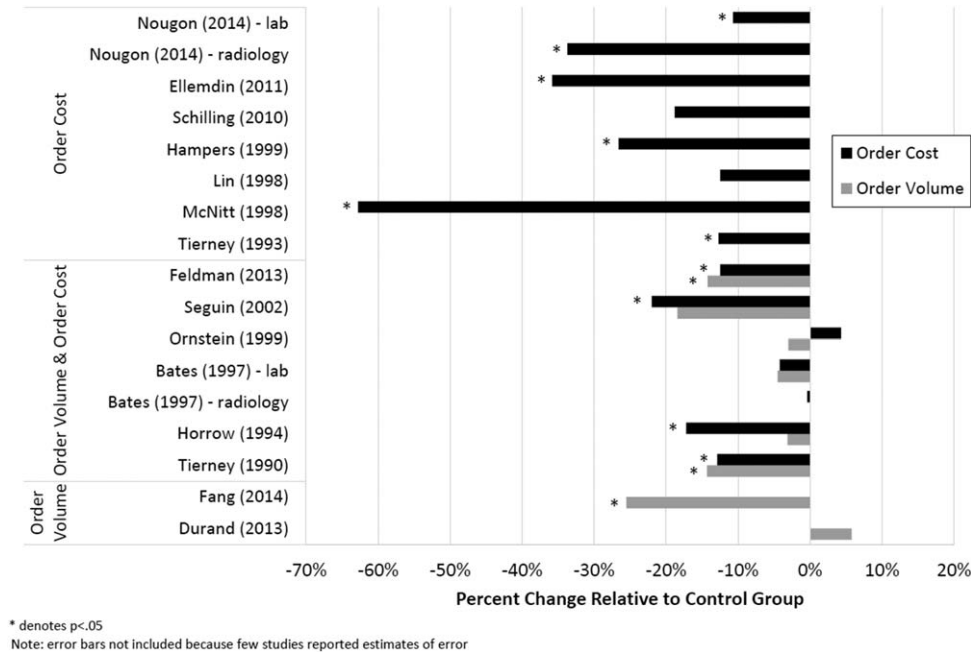


FIG. 1. Impact of price display on aggregate order costs and volume.

comparison modules,<sup>26</sup> or display of test turnaround times.<sup>14</sup> Seven of the 19 studies were conducted in the past decade, of which 5 displayed prices within an EHR.<sup>13–17</sup>

### Order Costs and Volume

Thirteen studies reported the numeric impact of price display on aggregate order costs (Table 2). Nine of these demonstrated a statistically significant ( $P < 0.05$ ) decrease in order costs, with effect sizes ranging from 10.7% to 62.8%.<sup>13,16,18,20,23,24,28–30</sup> Decreases were found for lab costs, imaging costs, and medication costs, and were observed in both the inpatient and outpatient settings. Three of these 9 studies were randomized. For example, in 1 study randomizing 61 lab tests to price display or no price display, costs for the intervention labs dropped 9.6% compared to the year prior, whereas costs for control labs increased 2.9% ( $P < 0.001$ ).<sup>16</sup> Two studies randomized by provider group showed that providers seeing order prices accrued 12.7% fewer charges per inpatient admission ( $P = 0.02$ ) and 12.9% fewer test charges per outpatient visit ( $P < 0.05$ ).<sup>29,30</sup> Three studies found no significant association between price display and order costs, with effect sizes ranging from a decrease of 18.8% to an increase of 4.3%.<sup>19,22,27</sup> These studies also evaluated lab, imaging, and medication costs, and included 1 randomized trial. One additional large study noted a 12.5% decrease in medication costs after initiation of price display, but did not statistically evaluate this difference.<sup>25</sup>

Eight studies reported the numeric impact of price display on aggregate order volume. Three of these demonstrated a statistically significant decrease in

order volume, with effect sizes ranging from 14.2% to 25.5%.<sup>14,16,30</sup> Decreases were found for lab and imaging tests, and were observed in both inpatient and outpatient settings. For example, 1 pre-post study displaying prices for inpatient send-out lab tests demonstrated a 25.5% reduction in send-out labs per 1000 patient-days ( $P < 0.001$ ), whereas there was no change for the control group in-house lab tests, for which prices were not shown.<sup>14</sup> The other 5 studies reported no significant association between price display and order volume, with effect sizes ranging from a decrease of 18.4% to an increase of 5.8%.<sup>17,20,22,27,28</sup> These studies evaluated lab, imaging, and medication volume. One trial randomizing by individual inpatient showed a nonsignificant decrease of 4.5% in lab orders per admission in the intervention group ( $P = 0.74$ ), although the authors noted that their study had insufficient power to detect differences less than 10%.<sup>27</sup> Of note, 2 of the 5 studies reporting nonsignificant impacts on order volume ( $-3.1%$ ,  $P = 0.56$ ; and  $-18.4%$ ,  $P = 0.12$ ) did demonstrate significant decreases in order costs ( $-17.1%$ ,  $P = 0.04$ ; and  $-22.0%$ ,  $P < 0.05$ ).<sup>20,28</sup>

There were an additional 2 studies that reported the impact of price display on order volume for individual orders only. In 1 time-series study showing lab test prices, there was a statistically significant decrease in order volume for 5 of 27 individual tests studied (using a Bonferroni-adjusted threshold of significance), with no tests showing a significant increase.<sup>15</sup> In 1 pre-post study showing prices for H2-antagonist drugs, there was a statistically significant 57.1% decrease in order volume for the high-cost medication, with a corresponding 58.7% increase in the low-cost

**TABLE 3. Study Quality and Limitations**

Study	Modified Downs & Black Score (Max Score 21)	Potential for Contamination Between Study Groups	Other Price Display Quality Criteria (Not Included in Downs & Black Score)		Incomplete Price Display Intervention or Data Collection
			Potential Confounders of Results Not Addressed by Study Design or Analysis	Potential Confounders of Results Not Addressed by Study Design or Analysis	
Fang et al. <sup>14</sup> 2014	14	None	Concurrent display of test turnaround time may have independently contributed to decreased test ordering	21% of reference lab orders were excluded from analysis because no price or turnaround-time data were available	None
Nougon et al. <sup>15</sup> 2015	16	None	Historical confounding may have existed due to pre-post study design without control group		None
Durand et al. <sup>17</sup> 2013	17	Providers seeing test prices for intervention tests (including lab tests in concurrent Feldman study) may have remained cost-conscious when placing orders for control tests	"Interference between units" likely occurred because intervention test ordering (eg, chest X-ray) was not independent of control test ordering (eg, CT chest)		None
Feldman et al. <sup>16</sup> 2013	18	Providers seeing test prices for intervention tests (including imaging tests in concurrent Durand study) may have remained cost-conscious when placing orders for control tests	"Interference between units" likely occurred because intervention test ordering (eg, CMP) was not independent of control test ordering (eg, BMP)		None
Horn et al. <sup>15</sup> 2014	15	None	None		None
Elemdin et al. <sup>18</sup> 2011	15	None	None		None
Schilling <sup>19</sup> 2010	12	None	None		None
Guterman et al. <sup>21</sup> 2002	14	None	Historical confounding may have existed due to pre-post study design without control group		None
Seguin et al. <sup>20</sup> 2002	17	None	Because primary outcome was not adjusted for length of stay, the 30% shorter average length of stay during intervention period may have contributed to decreased costs per admission; historical confounding may have existed due to pre-post study design without control group		None
Hampers et al. <sup>23</sup> 1999	17	None	Requirement that physicians calculate total charges for each visit may have independently contributed to decreased test ordering; historical confounding may have existed due to pre-post study design without control group	10% of eligible patient visits were excluded from analysis because prices were not displayed or ordering data were not collected	None
Ornstein et al. <sup>22</sup> 1999	15	Clinical pharmacists and pharmacy students involved in half of all patient contacts may have enhanced cost-awareness during control period	Emergence of new drugs during intervention period and an ongoing quality improvement activity to increase prescribing of lipid-lowering medications may have contributed to increased medication costs; historical confounding may have existed due to pre-post study design without control group	25% of prescription orders had no price displayed, and average prices were imputed for purposes of analysis	None
Lin et al. <sup>25</sup> 1998	12	None	Emergence of new drug during intervention period and changes in several drug prices may have contributed to decreased order costs; historical confounding may have existed due to pre-post study design without control group		None



**TABLE 3. Continued**

Study	Modified Downs & Black Score (Max Score 21)	Potential for Contamination Between Study Groups	Potential Confounders of Results Not Addressed by Study Design or Analysis	Incomplete Price Display Intervention or Data Collection
McNitt et al. <sup>24</sup> 1998	15	None	Intensive drug-utilization review and cost-reduction efforts may have independently contributed to decreased drug costs; historical confounding may have existed due to pre-post study design without control group	None
Bates et al. <sup>27</sup> 1997	18	Providers seeing test prices on intervention patients may have remembered prices or remained cost-conscious when placing orders for control patients	None	47% of lab tests and 26% of imaging tests were ordered manually outside of the trial's CPOE display system*
Vedsted et al. <sup>26</sup> 1997	5	None	Medication price comparison module may have independently influenced physician ordering	None
Horrow et al. <sup>28</sup> 1994	14	None	Historical confounding may have existed due to pre-post study design without control group	Ordering data for 2 medications during 2 of 24 weeks were excluded from analysis due to internal inconsistency in the data
Tierney et al. <sup>29</sup> 1993	20	None	Introduction of computerized order entry and menus for cost-effective ordering may have independently contributed to decreased test ordering	None
Tierney et al. <sup>30</sup> 1990	20	None	None	None
Everett et al. <sup>31</sup> 1983	7	None	None	None

NOTE: Abbreviations: BMP, basic metabolic panel; CMP, comprehensive metabolic panel; CPOE, computerized physician order entry; CT, computed tomography. \*Analysis in this study was performed both including and excluding these manually ordered tests; in this review we report the results excluding these tests

option.<sup>21</sup> These studies did not report impact on aggregate order costs. Two further studies in this review did not report outcomes numerically, but did state in their articles that significant impacts on order volume were not observed.<sup>26,31</sup>

Therefore, of the 19 studies included in this review, 17 reported numeric results. Of these 17 studies, 12 showed that price display was associated with statistically significant decreases in either order costs or volume, either in aggregate (10 studies; Figure 1) or for individual orders (2 studies). Of the 7 studies conducted within the past decade, 5 noted significant decreases in order costs or volume. Prices were embedded into an EHR in 5 of these recent studies, and 4 of the 5 observed significant decreases in order costs or volume. Only 2 studies from the past decade—1 from Belgium and 1 from the United States—incorporated prices into an EHR and reported aggregate order costs. Both found statistically significant decreases in order costs with price display.<sup>13,16</sup>

### Patient Safety and Provider Acceptability

Five studies reported patient-safety outcomes. One inpatient randomized trial showed similar rates of postdischarge utilization and charges between the intervention and control groups.<sup>29</sup> An outpatient randomized trial showed similar rates of hospital admissions, ED visits, and outpatient visits between the intervention and control groups.<sup>30</sup> Two pre-post studies showing anesthesia prices in hospital operating rooms included a quality assurance review and showed no changes in adverse outcomes such as prolonged postoperative intubation, recovery room stay, or unplanned intensive care unit admissions.<sup>24,25</sup> The only adverse safety finding was in a pre-post study in a pediatric ED, which showed a higher rate of unscheduled follow-up care during the intervention period compared to the control period (24.4% vs 17.8%,  $P < 0.01$ ) but similar rates of patients “feeling better” (83.4% vs 86.7%,  $P = 0.05$ ). These findings, however, were based on self-report during telephone follow-up with a 47% response rate.<sup>23</sup>

Five studies reported on provider acceptability of price display. Two conducted questionnaires as part of the study plan, whereas the other 3 offered general provider feedback. One questionnaire revealed that 83% of practices were “satisfied” or “very satisfied” with the price display.<sup>26</sup> The other questionnaire found that 81% of physicians felt the price display “improved my knowledge of the relative costs of tests I order” and similarly 81% “would like additional cost information displayed” for other orders.<sup>15</sup> Three studies reported subjectively that showing prices “initially caused questions from most physicians,”<sup>13</sup> but that ultimately, physicians “like seeing this information”<sup>27</sup> and gave feedback that was “generally positive.”<sup>21</sup> One study evaluated the impact of price display on provider cost knowledge. Providers in the

intervention group did not improve in their cost-awareness, with average errors in cost estimates exceeding 40% even after 6 months of price display.<sup>30</sup>

### Study Quality

Using a modified Downs and Black checklist of 21 items, studies in this review ranged in scores from 5 to 20, with a median score of 15. Studies most frequently lost points for being nonrandomized, failing to describe or adjust for potential confounders, being prone to historical confounding, or not evaluating potential adverse events.

We supplemented this modified Downs and Black checklist by reviewing 3 categories of study limitations not well-reflected in the checklist scoring (Table 3). The first was potential for contamination between study groups, which was a concern in 4 studies. For example, 1 pre-post study assessing medication ordering included clinical pharmacists in patient encounters both before and after the price display intervention.<sup>22</sup> This may have enhanced cost-awareness even before prices were shown. The second set of limitations, present in 12 studies, included confounders that were not addressed by study design or analysis. For example, the intervention in 1 study displayed not just test cost but also test turnaround time, which may have separately influenced providers against ordering a particular test.<sup>14</sup> The third set of limitations included unanticipated gaps in the display of prices or in the collection of ordering data, which occurred in 5 studies. If studies did not report on gaps in the intervention or data collection, we assumed there were none.

Even among the 5 randomized trials there were substantial limitations. For example, 2 trials used individual tests as the unit of randomization, although ordering patterns for these tests are not independent of each other (eg, ordering rates for comprehensive metabolic panels are not independent of ordering rates for basic metabolic panels).<sup>16,17</sup> This creates “interference between units” that was not accounted for in the analysis.<sup>32</sup> A third trial was randomized at the level of the patient, so was subject to contamination as providers seeing the price display for intervention group patients may have remained cost-conscious while placing orders for control group patients.<sup>27</sup> In a fourth trial, the measured impact of the price display may have been confounded by other aspects of the overall cost intervention, which included cost-effective test menus and suggestions for reasonable testing intervals.<sup>29</sup>

The highest-quality study was a cluster-randomized trial published in 1990 specifically measuring the effect of price display on a wide range of orders.<sup>30</sup> Providers and patients were separated by clinic session so as to avoid contamination between groups, and the trial included more than 15,000 outpatient visits. The intervention group providers ordered 14.3% fewer

tests than control group providers, which resulted in 12.9% lower charges.

## DISCUSSION

We identified 19 published reports of interventions that displayed real-time order prices to providers and evaluated the impact on provider ordering. There was substantial heterogeneity in study setting, design, and quality. Although there is insufficient evidence on which to base strong conclusions, these studies collectively suggest that provider price display likely reduces order costs to a modest degree. Data on patient safety were largely lacking, although in the few studies that examined patient outcomes, there was little evidence that patient safety was adversely affected by the intervention. Providers widely viewed display of prices positively.

Our findings align with those of a recent systematic review that concluded that real-time price information changed provider ordering in the majority of studies.<sup>7</sup> Whereas that review evaluated 17 studies from both clinical settings and simulations, our review focused exclusively on studies conducted in actual ordering environments. Additionally, our literature search yielded 8 studies not previously reviewed. We believe that the alignment of our findings with the prior review, despite the differences in studies included, adds validity to the conclusion that price display likely has a modest impact on reducing order costs. Our review contains several additions important for those considering price display interventions. We provide detailed information on study settings and intervention characteristics. We present a formal assessment of study quality to evaluate the strength of individual study findings and to guide future research in this area. Finally, because both patient safety and provider acceptability may be a concern when prices are shown, we describe all safety outcomes and provider feedback that these studies reported.

The largest effect sizes were noted in 5 studies reporting decreases in order volume or costs greater than 25%.<sup>13,14,18,23,24</sup> These were all pre-post intervention studies, so the effect sizes may have been exaggerated by historical confounding. However, the 2 studies with concurrent control groups found no decreases in order volume or cost in the control group.<sup>14,18</sup> Among the 5 studies that did not find a significant association between price display and provider ordering, 3 were subject to contamination between study groups,<sup>17,22,27</sup> 1 was underpowered,<sup>19</sup> and 1 noted a substantial effect size but did not perform a statistical analysis.<sup>25</sup> We also found that order costs were more frequently reduced than order volume, likely because shifts in ordering to less expensive alternatives may cause costs to decrease while volume remains unchanged.<sup>20,28</sup>

If price display reduces order costs, as the majority of studies in this review indicate, this finding carries broad implications. Policy makers could promote cost-

conscious care by creating incentives for widespread adoption of price display. Hospital and health system leaders could improve transparency and reduce expenses by prioritizing price display. The specific beneficiaries of any reduced spending would depend on payment structures. With shifts toward financial risk-bearing arrangements like accountable care organizations, healthcare institutions may have a financial interest in adopting price display. Because price display is an administrative intervention that can be developed within EHRs, it is potentially 1 of the most rapidly scalable strategies for reducing healthcare spending. Even modest reductions in spending on laboratory tests, imaging studies, and medications would result in substantial savings on a system-wide basis.

Implementing price display does not come without challenges. Prices need to be calculated or obtained, loaded into an EHR system, and updated periodically. Technology innovators could enhance EHR software by making these processes easier. Healthcare institutions may find displaying relative prices (eg, \$/\$/\$/\$) logistically simpler in some contexts than showing actual prices (eg, purchase cost), such as when contracts require prices to be confidential. Although we decided to exclude studies displaying relative prices, our search identified no studies that met other inclusion criteria but displayed relative prices, suggesting a lack of evidence regarding the impact of relative price display as an alternative to actual price display.

There are 4 key limitations to our review. First, the heterogeneity of the study designs and reported outcomes precluded pooling of data. The variety of clinical settings and mechanisms through which prices were displayed enhances the generalizability of our findings, but makes it difficult to identify particular contexts (eg, type of price or type of order) in which the intervention may be most effective. Second, although the presence of negative studies on this subject reduces the concern for reporting bias, it remains possible that sites willing to implement and study price displays may be inherently more sensitive to prices, such that published results might be more pronounced than if the intervention were widely implemented across multiple sites. Third, the mixed study quality limits the strength of conclusions that can be drawn. Several studies with both positive and negative findings had issues of bias, contamination, or confounding that make it difficult to be confident of the direction or magnitude of the main findings. Studies evaluating price display are challenging to conduct without these limitations, and that was apparent in our review. Finally, because over half of the studies were conducted over 15 years ago, it may limit their generalizability to modern ordering environments.

We believe there remains a need for high-quality evidence on this subject within a contemporary context to confirm these findings. The optimal methodology for evaluating this intervention is a cluster

randomized trial by facility or provider group, similar to that reported by Tierney et al. in 1990, with a primary outcome of aggregate order costs.<sup>30</sup> Given the substantial investment this would require, a large time series study could also be informative. As most prior price display interventions have been under 6 months in duration, it would be useful to know if the impact on order costs is sustained over a longer time period. The concurrent introduction of any EHR alerts that could impact ordering (eg, duplicate test warnings) should be simultaneously measured and reported. Studies also need to determine the impact of price display alone compared to “price comparison” displays (displaying prices for the selected order along with reasonable alternatives). Although price comparison was a component of the intervention in some of the studies in this review, it was not evaluated relative to price display alone. Furthermore, it would be helpful to know if the type of price displayed affects its impact. For instance, if providers are most sensitive to the absolute magnitude of prices, then displaying chargemaster prices may impact ordering more than showing hospital costs. If, however, relative prices are all that providers need, then showing lower numbers, such as Medicare prices or hospital costs, may be sufficient. Finally, it would be reassuring to have additional evidence that price display does not adversely impact patient outcomes.

Although some details need elucidation, the studies synthesized in this review provide valuable data in the current climate of increased emphasis on price transparency. Although substantial attention has been devoted by the academic community, technology start-ups, private insurers, and even state legislatures to improving price transparency to patients, less focus has been given to physicians, for whom healthcare prices are often just as opaque.<sup>4</sup> The findings from this review suggest that provider price display may be an effective, safe, and acceptable approach to empower physicians to control healthcare spending.

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