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Hospital-Level Care at Home for Acutely Ill Adults

A Randomized Controlled Trial

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Background: Substitutive hospital-level care in a patient's home may reduce cost, health care use, and readmissions while improving patient experience, although evidence from randomized controlled trials in the United States is lacking.

Objective: To compare outcomes of home hospital versus usual hospital care for patients requiring admission.

Design: Randomized controlled trial. (ClinicalTrials.gov: NCT03203759)

Setting: Academic medical center and community hospital.

Patients: 91 adults (43 home and 48 control) admitted via the emergency department with selected acute conditions.

Intervention: Acute care at home, including nurse and physician home visits, intravenous medications, remote monitoring, video communication, and point-of-care testing.

Measurements: The primary outcome was the total direct cost of the acute care episode (sum of costs for nonphysician labor, supplies, medications, and diagnostic tests). Secondary outcomes included health care use and physical activity during the acute care episode and at 30 days.

Results: The adjusted mean cost of the acute care episode was 38% (95% CI, 24% to 49%) lower for home patients than control patients. Compared with usual care patients, home patients had fewer laboratory orders (median per admission, 3 vs. 15), imaging studies (median, 14% vs. 44%), and consultations (median, 2% vs. 31%). Home patients spent a smaller proportion of the day sedentary (median, 12% vs. 23%) or lying down (median, 18% vs. 55%) and were readmitted less frequently within 30 days (7% vs. 23%).

Limitation: The study involved 2 sites, a small number of home physicians, and a small sample of highly selected patients (with a 63% refusal rate among potentially eligible patients); these factors may limit generalizability.

Conclusion: Substitutive home hospitalization reduced cost, health care use, and readmissions while increasing physical activity compared with usual hospital care.

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Hospitals are the standard of care for acute illness in the United States, but inpatient care is expensive—accounting for about one third of total medical expenditures (1)—and may be unsafe, particularly for older persons (2). Timely access to inpatient care is often poor: Hospital wards are typically at capacity, and average emergency department (ED) waits can be more than 6 hours (3). After hospital discharge, many patients have "posthospital syndrome," due in part to such factors as deconditioning and sleep deprivation (4), and almost 20% of Medicare patients are readmitted within 30 days of discharge (5).

A "home hospital" is the home-based provision of acute care services usually associated with the traditional inpatient hospital (6). Prior work suggests that home hospital care can reduce cost, maintain quality and safety, and improve patient experience for selected acutely ill adults who require traditional hospital-level care (7–16). Home hospital care is already provided in several developed countries, such as Australia and Spain (17, 18), but few nonrandomized studies have been done in the United States (7, 8, 16). We published the first pilot randomized controlled trial in the United States (19). Given the strong potential for confounding and bias in nonrandomized evaluations of substitutive care, we sought to strengthen the evidence base by replicating our prior trial with more patients.

METHODS

Design Overview

We performed a parallel-design, randomized controlled trial in which participants were randomly allocated to home hospital care (intervention) or traditional hospital care (control). We enrolled participants between 12 June 2017 and 16 January 2018; follow-up ended on 17 February 2018. Patients, study staff, and physicians were not blinded to allocation status. This internally funded study was stopped early (after enrolling 91 patients) in light of local operational needs to quickly increase home hospital capacity after positive interim outcomes were presented to hospital leadership. The trial protocol (**Supplement**, available at Annals.org) was approved by the Partners HealthCare institutional review board and registered at ClinicalTrials.gov (NCT03203759). All participants provided written informed consent before randomization.

Setting and Participants

Adult participants were recruited in the ED at Brigham and Women's Hospital (an academic medical

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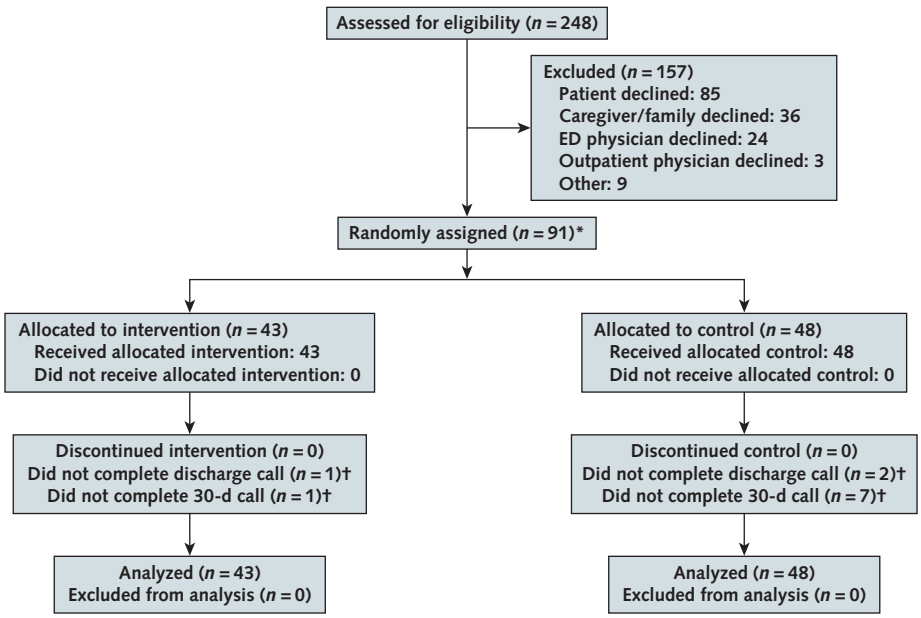
Figure. Study flow diagram.



ED = emergency department.
* Enrollment was stopped after 91 patients (76% of intended) were enrolled.
† Not completing a discharge call required estimation of postdischarge health care use through the electronic health record and incurred missing values for patient experience measures.

center) and Brigham and Women's Faulkner Hospital (a community hospital). A research assistant prescreened patients to ensure that they were not presenting for trauma or psychiatric evaluation and did not live outside the catchment area. After the ED attending physician decided to admit a patient, he or she would call the triage hospitalist as per usual protocol. If these physicians agreed that the patient met preliminary inclusion criteria, the home hospital team assessed the patient for eligibility, interest, and consent (Figure). All hospital-based attending physicians received education on the trial and its inclusion criteria. One goal of enrollment was minimal disruption to the ED; our tracking of various process measures (Appendix Table 1, available at Annals.org) showed minimal delay in the ED due to the intervention.

Participants were eligible for home hospital care if they resided within a 5-mile catchment area; had the capacity to consent (or could assent with the consent of a health care proxy who was physically present); were aged 18 years or older; and had a primary diagnosis of any infection, heart failure exacerbation, chronic obstructive pulmonary disease exacerbation, asthma exacerbation, or selected other conditions (Appendix Table 2, available at Annals.org). Patients were excluded if they resided in a long-term care or rehabilitation facility, required routine administration of controlled substances, required more than the assistance of 1 person to reach a bedside commode, or were considered to be at high risk for clinical deterioration on the basis of validated general and disease-specific risk algorithms (Appendix Table 2). Patients were not excluded on the basis of insurance status or living alone.

Randomization and Interventions

Eligible participants who provided informed consent were randomly assigned to usual care or home hospital by study staff. Randomization was stratified by infection, heart failure, chronic obstructive pulmonary disease or asthma, and other diagnosis; block sizes between 4 and 6 were randomly selected, and allocation was concealed via sealed opaque envelopes. An outside statistician generated the randomization using SAS (SAS Institute).

All patients received at least 1 daily visit from an attending general internist and 2 daily visits from a home health registered nurse (Partners HealthCare at Home), with additional visits as needed. If necessary, participants could receive medical meals (Community Servings, Boston, Massachusetts) and the services of a home health aide, social worker, physical therapist, or occupational therapist (Partners HealthCare at Home). Selected specialists could be consulted via telemedicine as needed. Eight nurses (7 women; mean experience, 15 years) worked the week's day shifts. Five general internists (2 women; mean time since residency, 1 year; 3 were hospitalists at Brigham and Women's Hospital) rotated on 7-day shifts. Training involved a 1-day didactic course and several days of shadowing physicians experienced in home medicine.

The home hospital service could provide respiratory therapies (such as oxygen), intravenous medications via infusion pump (Smiths Medical), in-home radiology, and

point-of-care blood diagnostics (Abbott Laboratories). All patients had continuous monitoring of temperature, heart rate, respiratory rate, telemetry, movement, and falls via a small skin patch (VitalConnect). This monitoring was done through machine-based algorithms, which produced alarms for review by both nurse and physician (delivered to their smartphones). Participants communicated with their home hospital team via telephone, encrypted video, and encrypted short message service (Everbridge). The home hospital attending physician was available 24 hours a day for urgent issues and visits. He or she made decisions about when patients were ready to be discharged and postdischarge plans. We did not mandate the use of treatment pathways or algorithms for the home hospital group.

Participants randomly assigned to the control group received usual care in the hospital from an attending general internist (usually a hospitalist) or cardiologist. These physicians typically worked a 7- to 14-day rotation with additional coverage from residents or physician assistants during the day and night (admitting patients, entering orders, and responding to nursing concerns). The aforementioned skin patch (placed while in the ED) tracked patient movement; hospital staff were unaware of the patch's purpose.

Outcomes and Follow-up

For both groups, study staff interviewed patients on admission, at discharge, and 30 days after discharge. On admission, patients reported sociodemographic characteristics and completed assessments of frailty (20), cognitive impairment (21), depression (22), emotional support (23), health literacy (24), quality of life (25), and functional status (26). Staff collected information from the electronic health record (EHR) on such items as insurance status.

Our primary outcome was the "direct cost" of the acute care episode, hereafter referred to simply as "cost." Physician labor (all attending physicians, residents, and physician assistants) was excluded from cost calculations because its cost is customarily separate from traditional facility billing and revenue. Thus, we calculated cost by summing the costs of nonphysician labor, supplies, monitoring equipment, medications, laboratory orders, radiology studies, and transport related to each patient's care during the hospitalization (**Appendix Table 3**, available at Annals.org). Both groups used an identical cost calculation, except for transport (not applicable to the control group), nonphysician labor, and case management. In the home group, we multiplied nonphysician labor hours by the appropriate hourly direct rate, including fringe benefits and travel time, to obtain cost; in the control group, we used nonphysician labor cost as reported in our institution's internal cost-accounting system that includes direct labor and fringe benefits on a patient level. Case management cost appears only in the home group because case management was done directly by the home hospital team but its cost to the hospital cannot be reliably allotted to a specific patient.

The costs of items that were paid for by the institution but are not necessarily directly applicable to a specific patient (for example, executive salaries) were not included in either group.

We secondarily studied health care use, physical activity, patient experience, safety, and quality during the acute care episode (**Appendix 1**, available at Annals.org). Health care use comprised laboratory orders, radiology studies, consultations, and length of stay. Physical activity was evaluated via time sedentary (<0.1 m/s^2) and time lying down. Patient experience measures were the 3-item Care Transitions Measure (27), the 15-item Picker patient experience questionnaire (28), whether the patient would recommend the hospital, and global experience; all were based on the 30-day postdischarge interview. Safety comprised inappropriate medications (29) and delirium (30). All measures were derived from the EHR or patients, except physical activity, which was observed via the skin patch.

We also measured cost and health care use in the 30 days after discharge using the same cost-accounting method. We tracked readmissions, distinct ED visits, primary care visits, and specialist visits. In addition to EHR records from all Partners HealthCare facilities (the health system that includes both study hospitals) and the Care Everywhere system that joins all institutions that use the Epic EHR, we asked participants during the 30-day postdischarge interview whether they had received any health care outside our system and added those visits to the cost estimates. This occurred in only 2 patients, who each received a single primary care visit outside Partners HealthCare. Costs for these 2 visits were extrapolated using similar visits from Brigham and Women's Hospital. If patients could not be reached 30 days after discharge (8 total patients, 1 in the home group and 7 in the control group), we used EHR data alone to estimate health care use and readmission rates and did not measure patient experience.

Statistical Analysis

To have an adequate sample size for the primary outcome and some secondary outcomes, we originally intended to enroll 120 patients. We first estimated the sample size needed to detect the 52% reduction in the cost of an acute care episode that we had observed in our pilot study (19). We required 19 patients per group to detect this difference with 90% power using a 2-sided α level of 0.05. Increasing the intended sample size to 60 patients per group allowed us to detect a smaller effect in the primary outcome and differences in some secondary outcomes. We did not account for multiple comparisons, and we report secondary outcomes descriptively only.

We present descriptive data with counts and percentages, means and 95% CIs, or medians and interquartile ranges, as appropriate. We first present unadjusted outcomes. For our primary outcome (cost), we did prespecified adjustment for sex, age, race/ethnicity, education, discharge diagnosis, and comorbid condition count (31). We used a generalized linear model assuming a γ distribution with a log link, given the skewed nature of cost

data. Because our cost analysis takes the perspective of the hospital, we also did a sensitivity analysis that included physician labor in cost (Appendix 2, available at Annals.org). We present cost data as the percentage of change from control (rather than absolute difference) because of the sensitive nature of these data. All tests for significance used a 2-sided *P* value of 0.05. We did all analyses in SAS, version 9.4 (SAS Institute).

Role of the Funding Source

The Partners HealthCare Center for Population Health funded the operational aspects of the clinical care team. The Center had no role in design, data collection, analysis, or the decision to submit the manuscript for publication. The Center gave comments on the manuscript. Internal departmental funds supported the evaluation efforts.

RESULTS

Patient Characteristics

Of the 248 patients who were screened for eligibility, 91 were enrolled and randomly assigned to a group (Figure; Appendix Table 4 [available at Annals.org] shows details of those who declined). In an unadjusted bivariate comparison, patients who declined to participate were more often female. All randomly assigned patients received their allocated treatment.

At baseline, patients were generally frail and chronically ill; were frequent users of hospital care; and had excellent emotional support, fair health literacy, fair health-related quality of life, and functional status limitations (Table 1). Approximately 25% of each group lived alone. Patients in the control group were younger, more often black, and less often insured through Medicare. They more often had full code status (that is, a desire for full resuscitation) and were less likely to have a home health aide; physicians more often would have been surprised if they had died within 1 year. The 2 groups had similar proportions of patients in the prespecified blocked strata (that is, broad categories) of infection, heart disease, respiratory disease, and other. Within the infection category, home patients had more pneumonia, more skin or soft tissue infection, and less diverticulitis than control patients.

Cost and Health Care Use

Mean unadjusted cost of the acute care episode was 41% lower for home patients than control patients ($P < 0.001$). Adjusted mean cost was 38% lower (95% CI, 24% to 49% lower; $P < 0.001$) (Table 2).

Mean unadjusted length of stay was 4.5 days (CI, 3.9 to 5.0 days) for home patients versus 3.8 days (CI, 3.3 to 4.4 days) for control patients. During the care episode, home patients had less imaging (median percentage of patients, 14% vs. 44%), had fewer laboratory orders (median per admission, 3 vs. 15 orders), and less often received consultations (median percentage of patients, 2% vs. 31%) (Table 3).

Mean unadjusted cost for the hospitalization and 30-day postdischarge period combined was 41% lower for home patients. Mean adjusted cost was 36% (CI, 20% to 49%) lower, with reduced use of home health services, more use of home hospice, and better follow-up with primary care (Table 2).

In a secondary analysis that included physician cost using the number of patients per physician in each group, adjusted cost of the acute care episode was 19% (CI, 4% to 31%) lower in the home group and adjusted cost of the acute and 30-day postdischarge period was 25% (CI, 10% to 38%) lower (Appendix 2).

Home patients were less often readmitted within 30 days after discharge (7% vs. 23%).

Safety, Quality, and Activity

Nine percent of home patients and 15% of control patients had a safety event (Table 4; Appendix Table 5 [available at Annals.org]). None of the home patients required emergency medical services or were transferred back to the hospital during their acute care episode. Pain scores (Table 4) and frequency of delirium (Appendix Table 5) were similar between groups. No home patients and 10% of control patients received inappropriate medications.

Home patients were less often sedentary (median percentage of day, 12% vs. 23%) and spent less of the day lying down (median percentage of day, 18% vs. 55%) (Table 4). Decrements in functional status at discharge and 30 days after discharge were considerable but seemed similar between groups (Table 4).

Patient Experience

Patients in both groups reported high global satisfaction with care (median score, 10 of 10 in home group vs. 9 of 10 in control group) and readiness to transition care from acute care (median score, 12 of 12 in home group vs. 11 of 12 in control group) (Table 4). Both groups would recommend their acute care experience (4 of 4; interquartile range, 0) and had high Picker patient experience scores (14 of 15; interquartile range, 2).

DISCUSSION

In this randomized controlled trial of acutely ill adults requiring hospital admission, home hospital care reduced cost, decreased health care use and 30-day readmissions, and improved physical activity compared with traditional hospital care without appreciable differences in quality, safety, or patient experience.

The home hospital model aims to get the right care to the right patient at the right time in the right place. However, the definition of "home hospital" varies widely both nationally and internationally (32, 33). Our model involved physician home visits with 24-hour physician coverage, twice-daily nurse visits, and home-based treatments to provide acutely ill patients with care similar to that received in a traditional hospital. It also offered cutting-edge connectivity (continuous monitoring, 24-hour access to video and texting, and virtual consultations), which makes it different from many home-based models in its ability to handle high patient acuity and include a high degree of medical decision making by physicians. Careful patient selection also minimized risk.

Table 1. Baseline Patient Characteristics*

Characteristic	Home (*n* = 43)	Control (*n* = 48)
Median age (IQR), *y*	80 (19)	72 (23)
Female sex	15 (35)	18 (38)
Race/ethnicity		
White	24 (56)	22 (46)
Black	6 (14)	14 (29)
Hispanic/Latino	8 (19)	8 (17)
Asian	4 (9)	2 (4)
Other	0 (0)	2 (4)
Partner status		
Partnered	16 (37)	18 (38)
Divorced	8 (19)	5 (10)
Widowed	9 (21)	6 (13)
Single, never partnered	10 (23)	18 (38)
Other	0 (0)	1 (2)
Lived alone	11 (26)	12 (25)
Primary language		
English	31 (72)	38 (79)
Spanish	8 (19)	6 (13)
Insurance		
Private	6 (14)	7 (15)
Medicare	21 (49)	17 (35)
Medicaid	4 (9)	5 (10)
Medicare and Medicaid	12 (28)	17 (35)
None	0 (0)	2 (4)
Education†		
Less than high school	15 (35)	15 (32)
High school	7 (16)	14 (30)
<4-y college	6 (14)	6 (13)
4-y college	7 (16)	7 (15)
>4-y college	8 (19)	5 (11)
Employment†		
Employed	11 (26)	10 (21)
Unemployed	2 (5)	7 (15)
Retired	30 (70)	30 (64)
Cigarette smoking		
Never	21 (49)	28 (58)
Current	6 (14)	6 (13)
Prior	16 (37)	14 (29)
Median PRISMA frailty score (IQR)‡	4 (3)	3 (3)
Median comorbid condition count (IQR), *n*§	4 (3)	3 (3)
Admitted to hospital in past 6 mo	15 (35)	18 (38)
Visited ED in past 6 mo	17 (40)	15 (31)
Median 8-Item Interview to Differentiate Aging and Dementia score (IQR)‖	1 (4)	2 (4)
Median PHQ-2 score (IQR)¶	0 (3)	0 (3)
Median PROMIS emotional support score (IQR)**	20 (0)	20 (0)
Median Brief Health Literacy Screening Tool score (IQR)††	13 (12)	13 (11)
Mean EuroQol VAS score (95% CI)‡‡	56 (50–62)	61 (54–68)
Median ADLs on admission (IQR), *n*§§	6 (5)	6 (3)
Median IADLs on admission (IQR), *n*‖‖	4 (7)	6 (6)
Full code status	27 (63)	43 (90)
Physician would be surprised if patient died within 1 y¶¶	21 (51)	33 (69)
Mean outpatient medications (95% CI), *n*	13 (10–15)	12 (10–14)
Had home health aide	17 (40)	10 (21)
Diagnosis***		
Infection	23 (53)	22 (46)
Pneumonia	11 (26)	10 (21)
Skin/soft tissue infection	8 (19)	3 (6)
Complicated urinary tract infection/pyelonephritis	4 (9)	4 (8)
Diverticulitis	0 (0)	5 (10)
Heart failure	7 (16)	8 (17)
Airway disease	6 (14)	7 (15)
Asthma	1 (2)	2 (4)
Chronic obstructive pulmonary disease	5 (12)	5 (10)

Continued on following page

Table 1–Continued

Characteristic	Home (*n* = 43)	Control (*n* = 48)
Other	7 (16)	11 (23)
Diabetes complication	2 (5)	4 (8)
End of life	1 (2)	1 (2)
Hypertensive urgency	2 (5)	0 (0)
Anticoagulation need	1 (2)	4 (8)
Gout exacerbation	1 (2)	0 (0)
Other	0 (0)	2 (4)

ADL = activity of daily living; ED = emergency department; IADL = instrumental ADL; IQR = interquartile range; PHQ-2 = Patient Health Questionnaire 2; PRISMA = Program of Research to Integrate the Services for the Maintenance of Autonomy; PROMIS = Patient-Reported Outcomes Measurement Information System; VAS = visual analogue scale.
* Values are numbers (percentages) unless otherwise indicated. Percentages may not sum to 100 due to rounding.
† Data missing for 1 control patient.
‡ Range, 0–7, where scores >2 indicate frailty.
§ Count of the patient's chronic comorbid conditions, out of the 20 conditions considered chronic by the Health and Human Services Office of the Assistant Secretary of Health (31).
‖ Range, 0–8, where scores >1 indicate cognitive impairment.
¶ Range, 0–6, where scores >2 indicate depression.
** Range, 4–20, where scores >17 indicate better-than-average emotional support.
†† Range, 4–20, where scores of 4–12 indicate limited health literacy, scores of 13–16 indicate marginal health literacy, and scores of 17–20 indicate adequate health literacy.
‡‡ Range, 0–100.
§§ Range, 0–6.
‖‖ Range, 0–8.
¶¶ Data missing for 2 home patients.
*** Block-randomized at the level of infection, heart failure, airway disease, and other.

Home hospital care may reduce cost because it delivers a combination of remote and in-person care that reduces nursing labor (similar patient–nurse ratio, but 2 visits at home vs. 24-hour care in the hospital), use of ancillary services and consultations, and readmissions. It may also deliver care in a more patient-centered manner: Patients can be surrounded by their family and friends, eat their own food, move around in their own home, and sleep in their own bed (without being awakened multiple times per night), all with the support of the home hospital team.

The reduction in readmission rate is particularly notable, especially given the magnitude of effect and the inability of many transitional care interventions to influence this outcome (34). Perhaps patients who receive acute care at home are less likely to develop "posthospital syndrome" because they sleep better; eat better; walk more; and become less deconditioned, malnourished, and sedated (4). Discharge planning may also be more effective at home because it occurs where patients and caregivers will be carrying out postdischarge tasks and can be tailored to the home environment. The first hypothesis is only partly supported by our results: Home patients were more active than but had functional status reductions similar to control patients, perhaps because of limitations in functional status measurement tools. Other components of these hypotheses were not specifically tested in this study and require further research.

This work builds substantially on our pilot study and corroborates previous work. Others providing home hospital care to acutely ill patients have shown reduced cost and decreased health care use while maintaining or improving quality, safety, and patient experience (7, 8). A randomized controlled trial in Australia found a 51% reduction in cost (13, 35). Few studies have measured 30-day postdischarge cost, and our reporting of unadjusted and log-adjusted mean is conservative when the sizable portion of patients readmitted in the control group is con-

Table 2. Relative Cost of Home Hospital Care to Traditional Hospital Care

Cost	Without Physician Labor		With Physician Labor*	
	Relative Reduction, %	*P* Value	Relative Reduction, %	*P* Value
Acute care episode				
Unadjusted cost†	41	<0.001	16	0.075
Adjusted mean cost (95% CI)‡	38 (24–49)	<0.001	19 (4–31)	0.017
Acute care episode and 30 d after acute care episode				
Unadjusted cost†	41	<0.001	29	0.007
Adjusted mean cost (95% CI)‡	36 (20–49)	<0.001	25 (10–38)	<0.001

* Appendix 1 (available at Annals.org) shows physician cost modeling. Model shown assumes actual mean number of patients per physician.
† Percentage of change in mean cost is calculated as [(control cost − home cost) ÷ (control cost)] × 100%. If percentage of change is negative, control group costs less; if percentage of change is positive, home group costs less.
‡ From a generalized linear model with a γ distribution and a log link that adjusted for sex, age, race/ethnicity, education, discharge diagnosis, and comorbid condition count.

Table 3. Patient Health Care Use*

Measure	Home (*n* = 43)	Control (*n* = 48)
During acute care episode		
Mean length of stay (95% CI), *d*	4.5 (3.9–5.0)	3.8 (3.3–4.4)
Intravenous medication during admission	30 (70)	39 (81)
Imaging during admission	6 (14)	21 (44)
Median laboratory orders per admission (IQR), *n*	3 (5)	15 (15)
Consultant session during admission	1 (2)	15 (31)
Physical or occupational therapy session during admission	0 (0)	8 (17)
Disposition		
Routine	28 (65)	32 (67)
Home health	10 (23)	15 (31)
Home hospice	4 (9)	1 (2)
Other	1 (2)	0 (0)
30 d after acute care episode		
Primary care visit ≤14 d after discharge†	22 (55)	19 (42)
30-d readmission†	3 (7)	11 (23)
For same condition as index hospitalization, *n/N*‡	1/3	6/11
30-d ED presentation†	3 (7)	6 (13)

ED = emergency department; IQR = interquartile range.
* Values are numbers (percentages) unless otherwise indicated. Percentages may not sum to 100 due to rounding.
† For 1 home patient and 7 control patients, these data were evaluated via medical record review only because the patients could not be reached for the 30-d telephone call.
‡ Out of all readmitted patients in each study group.

sidered. Federman and colleagues (16) recently showed reduced readmissions in a quasi-experimental home hospital study. Two randomized controlled trials in Italy for patients presenting with exacerbation of chronic obstructive pulmonary disease or heart failure had similar findings to ours and showed reduced readmissions (9, 36). Our findings regarding physical activity corroborate other work (15, 37).

Table 4. Quality, Physical Activity, Functional Status, and Experience*

Measure	Home (*n* = 43)	Control (*n* = 48)
Quality of care†		
Any safety event‡	4 (9)	7 (15)
Median pain score (IQR)§	0 (1)	0 (3)
Inappropriate medication use‖	0 (0)	5 (10)
Urinary catheter use	0 (0)	2 (4)
Restraint use	0 (0)	0 (0)
Activity each day		
Median percentage of day sedentary (IQR)	12 (15)	23 (23)
Median percentage of day lying down (IQR)	18 (32)	55 (66)
Functional status		
IADLs worse: admission to discharge¶	11 (26)	14 (31)
IADLs worse: admission to 30 d after discharge**	14 (37)	13 (34)
ADLs worse: admission to discharge¶	6 (14)	6 (13)
ADLs worse: admission to 30 d after discharge**	4 (11)	6 (16)
Patient experience		
Median global satisfaction score (IQR)**††	10 (1)	9 (1)
Median 3-item Care Transitions Measure score (IQR)¶‡‡	12 (1)	11 (3)
Median recommendation of hospital (IQR)**§§	4 (0)	4 (0)
Median Picker patient experience questionnaire score (IQR)‖‖	14 (2)	14 (3)

ADL = activity of daily living; IADL = instrumental ADL; IQR = interquartile range.
* Values are numbers (percentages) unless otherwise indicated.
† Standard inpatient quality measures for pneumonia and heart failure (e.g., β-blocker for heart failure with reduced ejection fraction, or smoking cessation counseling) were achieved equally in both groups (data not shown).
‡ Appendix Table 5 (available at Annals.org) shows detailed safety events.
§ Range, 0–10.
‖ Using the updated Beers Criteria (29).
¶ For 1 home patient and 3 control patients, these data are missing.
** For 1 home patient and 10 control patients, these data are missing.
†† Range, 0–10, where 0 indicates the worst possible hospital and 10 the best possible hospital.
‡‡ Range, 3–12.
§§ Range, 0–4, where 0 indicates "definitely would not recommend" and 4 indicates "definitely would recommend."
‖‖ Range, 0–15.

Unlike other studies, we found similar rates of delirium, changes in functional status, and length of stay between groups (7, 8, 16). Perhaps some patients will become delirious because of their severity of illness or frailty regardless of the location of their care; however, it is possible that the home hospital team better identified delirium or that delirium resolved more quickly at home. This issue requires further investigation. Regarding length of stay, clinicians may have experienced less pressure to discharge patients from acute care in the home, but this did not result in higher cost and may have contributed to lower readmission rates. We were surprised to observe similar decrements in functional status in both groups despite improved physical activity in home patients. Perhaps a more nuanced tool is required to capture differences in functional status, or perhaps the reduced use of physical and occupational therapy in the home group counteracted the increased physical activity. Alternately, home hospitalization may be insufficient to counteract the negative effect of acute illness on functional status.

Our study has limitations. First, we recruited from only 2 sites, and only 5 physicians delivered the home hospital intervention, limiting the generalizability of our findings. Our cost calculations may be less valid at an institution with different nurse staffing structures, and we cannot exclude the possibility that at least some of the results are due to a small number of clinicians delivering exceptional care. However, our academic center has a high standard of care overall. Second, our study was stopped early to facilitate local operational needs ("rollout" of the intervention to as many patients as possible). Third, our eligibility criteria included a broad list of conditions so that we could enroll patients typically admitted to the general medical service and meet our sample size estimate; this approach limited our ability to examine condition-specific outcomes. Furthermore, patients were carefully selected for lower risk for clinical deterioration, which limits the generalizability of our findings. Fourth, a substantial proportion (63%) of patients did not enroll—approximately the inverse of prior work (7)—mostly because patients and families declined to participate. This was likely due to our randomization scheme, which allowed us to approach patients only just before "rolling upstairs," a time when most patients had already mentally prepared for traditional admission. However, few differences existed between those who did and did not choose to enroll (Appendix Table 4). Fifth, our study was small and does not allow us to exclude an increase in patient safety events with home hospital. Finally, our prespecified primary outcome excluded physician cost to mirror hospital payment structures; however, our secondary analysis included physician cost and had similar, albeit attenuated, findings. We also could not report revenue.

Compared with traditional hospital care, home hospital care for acutely ill adults reduced cost, decreased health care use and 30-day readmissions, and improved physical activity. Reimagining the best place to care for selected acutely ill adults holds enormous potential. Further work is needed to better understand the conditions and illness severity of patients who could be successfully cared for at home; new technologies we might deploy; and more efficient workflows that may optimize home-based teams and allow for expansion, both on a small scale and at a regional or national level. If scaled, home hospital teams could transform how acute care is delivered in the United States, with potential improvements in cost, health care use, and readmissions.

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Appendix 1: Additional Secondary Outcomes

Safety measures included routinely reported adverse events (such as falls and hospital-acquired conditions), delirium (captured by the Confusion Assessment Method, [38] documented every 8 hours for control patients as part of usual care and twice daily for home patients), and the unexpected return to hospital rate (intervention group only). Appendix Table 5 lists these and other safety measures.

Quality measures included pertinent inpatient quality measures from the Centers for Medicare & Medicaid Services (for example, angiotensin-converting enzyme inhibitor in a patient with heart failure with reduced ejection fraction), pain scores, and inappropriate medication use (using updated Beers Criteria). We considered hospital-acquired disability to be any reduction in a patient's activities of daily living or instrumental activities of daily living between admission and discharge (37).

Appendix Table 6 lists the various secondary and exploratory outcomes that we do not present in this article.

Appendix 2: Cost Calculation Sensitivity Analyses, Including Physician Labor

Brigham and Women's Hospital (BWH) does not use a direct care model like home hospital (that is, physicians at BWH always work with residents or physician assistants). The attending physician–patient ratios for home hospital and BWH are capped at 1:4 and 1:16, respectively. However, the BWH daytime attending physician is assisted by a nocturnist and 3 daytime, 2 twilight, and 2 nighttime residents, or by physician assistant equivalents; in effect, this requires more physicians per patient than home hospital. In addition, at nearby academic medical centers that do have direct care models (that is, no assistance from a resident or advanced practice provider), attending physicians typically see 8 patients and still require overnight attending coverage.

To calculate the direct cost of physician care per patient in the control group, we obtained confidential data from the hospital medicine unit at BWH. For each hospital role (attending daytime physician, attending nocturnist, physician assistant, and resident physician), we obtained the following data: starting salary, salary with fringe benefits, shifts per year, patient load, and full-time equivalents required for load. From these data, we calculated cost per year, cost per day, and cost per patient per day.

To calculate cost per patient, we multiplied the patient's length of stay by cost per patient per day.

To calculate the direct cost of physician care per patient in the home group, we obtained the same data noted earlier from our own records. Because the home hospital service was operating at less than its fully envisioned capacity, it did not fully leverage the physician's time. We therefore did a sensitivity analysis modeling the physician's efficiency. We started with the census (that is, patient count per physician) at which the home hospital team was able to operate during the study (current census, 3.5). We also considered that a low census would be 2 patients (for example, under conditions of low enrollment). Finally, we are planning to increase the physician's census to 8 in the near term and wanted to model this planned efficiency of 8:

Low physician efficiency: census = 2
Current physician efficiency: census = 3.5
Planned physician efficiency: census = 8

In Appendix Table 7, we present the same cost calculation methodology as in the main analysis, with the addition of physician cost. Adjustment was exactly as described in the article.

Appendix Table 1. Operational Process Measures

Process Measure	Home (n = 43)	Control (n = 48)
Mean time from admission decision to assessment by research assistant (95% CI), *min*	11 (0–25)	12 (4–20)
Mean time from research assistant assessment to completed enrollment (95% CI), *min*	29 (21–36)	27 (21–36)
Mean time from completed enrollment to dismissal from ED (95% CI), *min*	66 (54–78)	54 (28–80)

ED = emergency department.

Appendix Table 2. Detailed Inclusion and Exclusion Criteria

Inclusion

- Clinical
  - Aged ≥18 y
  - Primary or possible diagnosis of any infection, heart failure exacerbation, COPD exacerbation, asthma exacerbation, chronic kidney disease requiring diuresis, diabetes and its complications, gout exacerbation, hypertensive urgency, previously diagnosed atrial fibrillation with rapid ventricular response, anticoagulation needs (e.g., venous thromboembolism), or a patient at the end of life who desires only medical management

Exclusion

- Social
  - Not domiciled
  - No working heat (October–April), no working air conditioning if forecast >27 °C (June–September), or no running water
  - Receiving methadone requiring daily pickup of medication
  - In police custody
  - Resides in facility that provides onsite medical care (e.g., skilled-nursing facility)
  - Domestic violence screen positive (39)
- Clinical
  - Acute delirium, as determined by the Confusion Assessment Method
  - Cannot establish peripheral access in ED
  - Secondary condition: active nonmelanoma/prostate cancer, end-stage renal disease, acute myocardial infarction, acute cerebral vascular accident, or acute hemorrhage
  - Primary diagnosis requires multiple or routine administrations of controlled substances for pain control
  - Cannot independently ambulate to bedside commode
  - As deemed by on-call physician, patient likely to require any of the following procedures: computed tomography, magnetic resonance imaging, endoscopic procedure, blood transfusion, cardiac stress test, or surgery
  - For pneumonia:
    - Most recent CURB-65 score >3 (40)
    - Most recent SMRT-CO score >2 (41)
    - Absence of clear infiltrate on imaging
    - Cavitary lesion on imaging
    - Pulmonary effusion of unknown etiology
    - Oxygen saturation <90% despite 5 L of oxygen
  - For heart failure:
    - Has a left ventricular assist device
    - GWTG-HF (42) (>10% in-hospital mortality) or ADHERE (43) (high risk or intermediate risk 1)
    - Severe pulmonary hypertension
  - For complicated urinary tract infection:
    - Absence of pyuria
    - Most recent qSOFA score >1 (44)
  - For other infection:
    - Most recent qSOFA score >1 (44)
  - For COPD:
    - BAP-65 score >3
  - For asthma:
    - Peak expiratory flow <50% of normal: exercise caution
  - For diabetes and its complications:
    - Requires IV insulin
  - For hypertensive urgency:
    - Systolic blood pressure >190 mm Hg
    - Evidence of end-stage organ damage
  - For atrial fibrillation with rapid ventricular response:
    - Likely to require cardioversion
    - New atrial fibrillation with rapid ventricular response
    - Unstable blood pressure, respiratory rate, or oxygenation
    - Despite IV β and/or calcium-channel blockade in the ED, HR remains >125 beats/min and systolic blood pressure remains different from baseline
    - <1 h has elapsed with HR <125 beats/min and systolic blood pressure similar to or higher than baseline

ADHERE = Acute Decompensated Heart Failure National Registry; BAP-65 = elevated Blood urea nitrogen, Altered mental status, Pulse >109 beats/min, and age >65 y; COPD = chronic obstructive pulmonary disease; CURB-65 = Confusion, Urea, Respiratory rate, Blood pressure, and age ≥65 y; ED = emergency department; GWTG-HF = American Heart Association Get With the Guidelines–Heart Failure; HR = heart rate; IV = intravenous; qSOFA = quick Sequential [Sepsis-related] Organ Failure Assessment; SMRT-CO = Systolic blood pressure, Multilobar chest radiography involvement, Respiratory rate, Tachycardia, Confusion, and Oxygenation.

Appendix Table 3. Cost Calculation Details*

Cost Type	Home	Control
Labor (including fringe benefits)		
Nurse	X	X
Aide	X	X
Occupational therapist	X	X
Physical therapist	X	X
Social worker	X	X
Nurse-level case management/care coordination	X	–
Supplies		
IV care	X	X
Wound care	X	X
Dressings	X	X
Oxygen	X	X
Nebulizer	X	X
Monitoring equipment	X	X
Communication equipment	X	–
Food	X	X
Other	X	X
Medications	X	X
Diagnostics		
Imaging		
Facility-based	X	X
Point-of-care	X	–
Laboratory tests		
Facility-based	X	X
Point-of-care	X	X
Transport		
Patient	X	–
RN	X	–
Parking	X	–

IV = intravenous; RN = registered nurse.
* We calculated cost by summing all of the various cost streams for each group where an "X" is marked.

Appendix Table 4. Characteristics of Patients Who Declined to Enroll*

Characteristic	Home (*n* = 43)	Control (*n* = 48)	Declined (*n* = 157)
Median age (IQR), *y*	80 (19)	72 (23)	74 (24)
Female sex	15 (35)	18 (38)	107 (68)
Race/ethnicity			
White	24 (56)	22 (46)	76 (48)
Black	6 (14)	14 (29)	34 (22)
Hispanic/Latino	8 (19)	8 (17)	40 (25)
Asian	4 (9)	2 (4)	4 (3)
Other	0 (0)	2 (4)	2 (1)
Primary language			
English	31 (72)	38 (79)	121 (77)
Spanish	8 (19)	6 (13)	28 (18)
Insurance			
Private	6 (14)	7 (15)	37 (24)
Medicare	21 (49)	17 (35)	83 (53)
Medicaid	4 (9)	5 (10)	6 (4)
Medicare and Medicaid	12 (28)	17 (35)	29 (18)
None	0 (0)	2 (4)	2 (1)
Admitted to hospital in past 6 mo	15 (35)	18 (38)	79 (50)
Visited ED in past 6 mo	17 (40)	15 (31)	63 (40)

ED = emergency department; IQR = interquartile range.
* Values are numbers (percentages) unless otherwise indicated.

Appendix Table 5. Patient Safety*

Measure	Home (*n* = 43)	Control (*n* = 48)
Fall	1 (2)	0 (0)
Delirium	3 (7)	4 (8)
DVT/PE	0 (0)	0 (0)
New pressure ulcer	0 (0)	0 (0)
Thrombophlebitis at peripheral IV site	0 (0)	0 (0)
CAUTI	0 (0)	0 (0)
New *Clostridium difficile*	0 (0)	1 (2)
New MRSA	0 (0)	1 (2)
New arrhythmia	0 (0)	0 (0)
Hypokalemia	1 (2)	1 (2)
Acute kidney injury	1 (2)	2 (4)
Transfer back to hospital	0 (0)	NA
Death (unplanned) during admission	0 (0)	0 (0)
Death (unplanned) ≤30 d after discharge	0 (0)	1 (2)
Death (all-cause) during admission	0 (0)	0 (0)
Death (all-cause) ≤30 d after discharge	3 (7)	2 (4)

CAUTI = catheter-associated urinary tract infection; DVT/PE = deep venous thrombosis/pulmonary embolism; IV = intravenous; MRSA = methicillin-resistant *Staphylococcus aureus*; NA = not applicable.
* Values are numbers (percentages).

Appendix Table 6. Plan for Additional Variables

Measure	Secondary or Exploratory	Reason Not Included
Direct margin	Secondary	Sensitive data
Direct margin, modeled with backfill	Secondary	Sensitive data
Total reimbursement, 30 d after discharge	Exploratory	Sensitive data
Intravenous fluids, days	Exploratory	Will present in a follow-up manuscript
Intravenous diuretics, days	Exploratory	Will present in a follow-up manuscript
Intravenous antibiotics, days	Exploratory	Will present in a follow-up manuscript
Oxygen requirement, days	Exploratory	Will present in a follow-up manuscript
Nebulizer treatment, days	Exploratory	Will present in a follow-up manuscript
Skilled-nursing facility use, days	Exploratory	Will present in a follow-up manuscript
Home health use, days	Exploratory	Will present in a follow-up manuscript
Hours of sleep per day	Secondary	Will present in a follow-up manuscript
Hours of sleep per night	Exploratory	Will present in a follow-up manuscript
Hours of activity per day	Secondary	Will present in a follow-up manuscript
Hours of activity per night	Exploratory	Will present in a follow-up manuscript
Hours of sitting upright per day	Secondary	Will present in a follow-up manuscript
Hours of sitting upright per night	Exploratory	Will present in a follow-up manuscript
Daily steps	Secondary	Will present in a follow-up manuscript
Pneumococcal vaccination, if appropriate	Exploratory	Less clinically impactful
Influenza vaccination, if appropriate	Exploratory	Less clinically impactful
Smoking cessation counseling, if appropriate	Exploratory	Less clinically impactful
Evaluation of EF scheduled or completed if not done within 1 y	Exploratory	Less clinically impactful
Angiotensin-converting enzyme inhibitor or angiotensin-receptor blocker for HFrEF (EF <40%)	Exploratory	Less clinically impactful
β-Blocker for HFrEF (EF <40%)	Exploratory	Less clinically impactful
Aldosterone antagonist for HFrEF (EF <40%)	Exploratory	Less clinically impactful
Lipid-lowering medication for coronary artery disease, peripheral vascular disease, cerebrovascular accident, or diabetes	Exploratory	Less clinically impactful
Smoking status after discharge	Exploratory	Less clinically impactful
>3 medications added to medication list	Exploratory	Will present in a follow-up manuscript
EuroQol 5D-5L	Secondary	Will present in a follow-up manuscript
Short-Form 1	Secondary	Will present in a follow-up manuscript
Walk around ward/home	Exploratory	Will present in a follow-up manuscript
Get to (noncommode) bathroom	Exploratory	Will present in a follow-up manuscript
Walk 1 flight of stairs	Exploratory	Will present in a follow-up manuscript
Visit with friends/family	Exploratory	Will present in a follow-up manuscript
Walk outside around home	Exploratory	Will present in a follow-up manuscript
Go shopping	Exploratory	Will present in a follow-up manuscript
Qualitative interviews	Exploratory	Will present in a follow-up manuscript
RN–patient ratio	Exploratory	Will present in a follow-up manuscript
Number of RN visits	Exploratory	Will present in a follow-up manuscript
Number of "on-call" physician interactions (video or telephone)	Exploratory	Will present in a follow-up manuscript
Number of "on-call" physician in-person visits	Exploratory	Will present in a follow-up manuscript
Duration of first RN visit	Exploratory	Will present in a follow-up manuscript
Duration of subsequent RN visit	Exploratory	Will present in a follow-up manuscript
Clinician focus group	Exploratory	Will present in a follow-up manuscript

EF = ejection fraction; HFrEF = heart failure of reduced EF; RN = registered nurse.

Appendix Table 7. Sensitivity Analysis Including Physician Cost

Cost	Low Efficiency		Current Efficiency		Planned Efficiency	
	Relative Reduction, %	*P* Value	Relative Reduction, %	*P* Value	Relative Reduction, %	*P* Value
Acute care episode						
Unadjusted mean cost*	−15	0.96	16	0.075	34	<0.001
Adjusted mean cost (95% CI)†	−5 (−24 to 11)	0.54	19 (4 to 31)	0.017	37 (25 to 47)	<0.001
Acute care episode and 30 d after acute care episode						
Unadjusted mean cost*	16	0.056	29	0.007	39	<0.001
Adjusted mean cost (95% CI)†	12 (−5 to 27)	0.15	25 (10 to 38)	>0.001	35 (22 to 47)	<0.001

* Percentage of change in mean cost is calculated as [(control cost − home cost) ÷ (control cost)] × 100%. If percentage of change is negative, control group costs less; if percentage of change is positive, home group costs less.
† From a generalized linear model with a γ distribution and a log link that adjusted for sex, age, race/ethnicity, education, discharge diagnosis, and comorbid condition count.

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