The Impact of the Organization of High-Dependency Care on Acute Hospital Mortality and Patient Flow for Critically Ill Patients

Hannah Wunsch^{1,2,3}, David A. Harrison⁴, Andrew Jones^{4,5}, and Kathryn Rowan⁴

¹Department of Critical Care Medicine, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada; ²Department of Anesthesia, University of Toronto, Toronto, Ontario, Canada; ³Department of Anesthesiology, College of Physicians and Surgeons, Columbia University, New York, New York; ⁴Intensive Care National Audit and Research Centre, London, United Kingdom; and ⁵Department of Intensive Care, Guy's and St Thomas's NHS Foundation Trust, King's Health Partners, London, United Kingdom

Abstract

Rationale: Little is known about the utility of provision of high-dependency care (HDC) that is in a geographically separate location from a primary intensive care unit (ICU).

Objectives: To determine whether the availability of HDC in a geographically separate unit affects patient flow or mortality for critically ill patients.

Methods: Admissions to ICUs in the United Kingdom, from 2009 to 2011, who received Level 3 intensive care in the first 24 hours after admission and subsequently Level 2 HDC. We compared differences in patient flow and outcomes for patients treated in hospitals providing some HDC in a geographically separate unit (dual HDC) with patients treated in hospitals providing all HDC in the same unit as intensive care (integrated HDC) using multilevel mixed effects models.

Measurements and Main Results: In 192 adult general ICUs, 21.4% provided dual HDC. Acute hospital mortality was no different for patients cared for in ICUs with dual HDC versus those with integrated HDC (adjusted odds ratio, 0.94 [0.86–1.03]; $P = 0.16$). Dual HDC was associated with a decreased likelihood of a delayed discharge from the primary unit. However, total duration of critical care and the likelihood of discharge from the primary unit at night were increased with dual HDC.

Conclusions: Availability of HDC in a geographically separate unit does not impact acute hospital mortality. The potential benefit of decreasing delays in discharge should be weighed against the increased total duration of critical care and greater likelihood of a transfer out of the primary unit at night.

Keywords: intensive care unit; mortality; length of stay; intermediate care facilities

Intensive care (IC) is a limited and expensive resource. High-dependency care (HDC; also called “step-down” or “intermediate care”) offers a less intensive and less expensive level of care for patients who either do not, or no longer, require IC (1). Some hospitals provide IC and HDC in single integrated units, whereas others provide some HDC in geographically separate units (2). Despite the high mortality for critically ill patients and the expense of

critical care services, few data exist on the impact of different organizational models for provision of such care (3). In particular, few studies have addressed the impact on patient flow and outcome of the provision of HDC, either integrated with IC or in a separate unit (4–7). With recognition that transitions of care out of IC may be a period of risk for patients (8), the physical location and flexibility of beds becomes important. In particular, the use of separate

HDC beds may introduce additional transitions of care that could lead to complications and increased mortality. Alternatively, receipt of HDC in a separate location may mean these patients are not disadvantaged because of “sicker” patients nearby, and receive more appropriately tailored care.

The Department of Health in the United Kingdom, in 2000, published a recommendation that critical care beds

(Received in original form August 22, 2014; accepted in final form December 6, 2014)

Supported by internal funding from the Intensive Care National Audit and Research Centre; from the National Institute on Aging through Award Number K08AG038477 (H.W.); and from the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant Number UL1 RR024156 (H.W.).

Author Contributions: Study concept and design, H.W., D.A.H., and K.R. Data analysis, H.W. and D.A.H. Interpretation of data, H.W., D.A.H., A.J., and K.R. Drafting of the manuscript, H.W., D.A.H., A.J., and K.R.

Correspondence and requests for reprints should be addressed to Hannah Wunsch, M.D., M.Sc., Department of Critical Care Medicine, Sunnybrook Health Sciences Centre, 2075 Bayview Avenue, Room D1.08, Toronto, ON, M4N 3M5 Canada. E-mail: hannah.wunsch@sunnybrook.ca

This article has an online supplement, which is accessible from this issue's table of contents at www.atsjournals.org

Am J Respir Crit Care Med Vol 191, Iss 2, pp 186–193, Jan 15, 2015

Copyright © 2015 by the American Thoracic Society

Originally Published in Press as DOI: 10.1164/rccm.201408-1525OC on December 10, 2014

Internet address: www.atsjournals.org

At a Glance Commentary

Scientific Knowledge on the

Subject: Transitioning out of intensive care remains a challenge. The potential benefits or harms of providing some high-dependency care (HDC) in beds that are in a geographically separate unit, as compared with providing all HDC in the same, primary intensive care unit (ICU), remains uncertain.

What This Study Adds to the

Field: Critically ill patients cared for in ICUs with some provision of HDC in a geographically separate unit had similar risk-adjusted acute hospital mortality compared with patients cared for in primary ICUs with all HDC provided in the same unit. Provision of geographically separate HDC was associated with a decreased likelihood of delay in discharge from the primary unit. This potential benefit must be balanced against the finding of increased total duration of critical care and an increase in the percentage of discharges from the primary unit occurring at night.

should be developed and used “flexibly” (i.e., capable of providing both IC and HDC) and most hospitals have adopted this approach of colocation of IC and HDC within a single integrated unit (9). We took advantage of the existence of variation in the current provision of IC and HDC across hospitals in the National Health Service (NHS) in the United Kingdom. Focusing solely on the “step-down” or transition role of HDC, after a period of IC, we sought to explore the impact on outcome and patient flow of the provision of some HDC in geographically separate units. We also examined whether provision of HDC in geographically separate units was affected by involvement of noncritical care physician staffing.

Methods

We conducted a cohort study using data from adult general (mixed medical/surgical) critical care units participating in the Intensive Care National Audit and Research

Centre Case Mix Program from January 2009 through December 2011 (10). Bed numbers were determined from data routinely collected for the Case Mix Program. Data on the organizational provision of HDC were collected either by direct telephone or in-person contact with critical care staff at each hospital. Newly participating critical care units that contributed less than 50 admissions to the Case Mix Program during the study period and/or hospitals where we could not confirm the organizational provision of HDC were excluded. In addition, for hospitals providing some HDC in geographically separate units, we ascertained whether HDC in the geographically separate unit was the responsibility of solely critical care physicians, solely noncritical care physicians (i.e., medical or surgical), or through a joint model of care; all critical care (IC and HDC) delivered in single integrated units was by critical care physicians.

Exposure and Outcomes

The United Kingdom uses standard definitions for levels of critical care provided to patients. Level 3 (IC) is defined as “patients requiring advanced respiratory support alone or support of at least two failing organ systems.” This level includes all complex patients requiring support for multiorgan failure. Level 2 (HDC) is defined as “patients requiring more detailed observation or intervention including support for a single failing organ system (excluding invasive mechanical ventilation which is deemed Level 3 IC) or post-operative care and those stepping down from higher levels of care.” Additionally, lower levels of care are defined as follows: Level 1, “patients at risk of their condition deteriorating, or those relocated from higher levels of care, whose needs can be met on an acute ward with additional advice and support from the critical care team”; and Level 0, “ward care” (9). For the purposes of this study, we defined critically ill patients as those patients requiring the highest level care (Level 3 IC) within the first 24 hours after admission to the primary critical care unit and who subsequently received some Level 2 (HDC), either within the primary unit or in a geographically separate unit.

Our primary exposure for patients was at the hospital level, and was admission to

a primary critical care unit that had the availability and use of HDC in a geographically separate unit in the hospital. The geographically separate unit had to be used for transitioning patients after IC in the primary unit. We refer to these primary units as having availability of “dual HDC” because there was the option for patients to receive Level 2 HDC either in the primary unit or in the geographically separate unit. The baseline comparison group was admission to a primary unit that provided HDC in a single integrated unit (“integrated HDC”).

The primary outcome was acute hospital mortality. Secondary measures of patient flow were total duration of critical care (Level 3 IC plus Level 2 HDC, the latter delivered either in the primary unit or in a geographically separate unit) and the total length of acute hospital stay. With respect to the primary unit, we assessed the frequency of discharges that occurred at night (defined primarily by a “narrower” definition, 00:00–04:59, and then secondarily by a “broader” definition, 22:00–07:59) (11) and the percentage of patients readmitted to the primary unit. We examined any delay in discharge from the primary unit, defined as the median number of days of Level 1 and Level 0 care provided there (excluding care provided for patients declared brain dead). We also examined costs of critical care by assigning the estimates of costs for providing Level 3 IC and Level 2 HDC based on reference costs per day for adult critical care in the United Kingdom (2010–2011 NHS Trust Critical Services). Average costs for Level 3 IC and Level 2 HDC were generated by averaging the weighted estimates of costs for the support of two to six failing organ systems (Level 3) and zero to one failing organ systems (Level 2) and then applying these estimates to each patient based on the number of Level 3 and Level 2 days of care received (12).

Data Analysis

We included all patients who received Level 3 IC in the first 24 hours in the primary critical care unit and who subsequently received Level 2 HDC. Admissions to the primary unit who were transferred in from another critical care unit were excluded (see Figure E1 in the online supplement). The exclusion of patients who received Level 3 IC in the first 24 hours in the primary unit but did not subsequently receive Level 2

HDC primarily excluded patients who died while still receiving the highest level care (Level 3 IC) in the primary unit.

For patients in primary critical care units with dual HDC, we first calculated the ratio of HDC beds in the geographically separate unit to critical care beds in the primary unit and the percentage of patients who were discharged for HDC to the geographically separate unit (vs. directly to the ward). We assessed whether there was a relationship between the availability of separate HDC beds (the ratio of beds in the geographically separate unit to those in the primary unit) and the percentage of patients discharged from the primary unit to the geographically separate unit. We assessed correlation using the Spearman correlation coefficient.

For hospitals with either dual or integrated HDC, we compared hospital and unit characteristics. We then compared the case mix characteristics of patients admitted to primary units with either dual or integrated HDC. We performed univariable analyses of the association between receiving care in a primary unit with dual (vs. integrated) HDC and both outcome (acute hospital mortality) and patient flow using logistic and linear regression. Data on length of stay variables were log transformed because of their skewed nature. Costs were assessed using means (13). We then performed multivariable linear and logistic regression, with random effects for each unit, adjusting for acute severity of illness using the components of the 2011 updated Intensive Care National Audit and Research Centre risk prediction model (14) and accounting for the type of hospital (university, university-affiliated, or nonuniversity). We report results as the adjusted odds ratios, the adjusted relative difference for length of stay (calculated by exponentiating the coefficient from the log-linear regression), and the adjusted mean difference for costs.

We also assessed acute hospital mortality stratifying primary critical care units with dual HDC in two ways: based on the percentage of patients discharged for HDC to the geographically separate unit (vs. directly to the ward), in tertiles of percentage of discharges to assess whether a “dose-response” relationship existed based on the availability of separate HDC beds; and based on the reported physician staffing (solely critical care

physicians, solely noncritical care physicians, joint model of staffing) of the geographically separate unit. Database management and statistical analyses were performed using Excel (Microsoft, Redmond, WA) and Stata 12.0 (StataCorp LP, College Station, TX).

Results

Organization

A total of 192 intensive care units (ICUs; primary critical care units) were included, with 41 (21.4%) in acute hospitals with availability of HDC in a geographically separate unit, termed dual HDC (Table 1). Primary critical care units with dual HDC were more often in university hospitals (34.2% vs. 23.8%). Primary units with dual HDC had, on average, slightly fewer beds in the primary unit: median of eight (interquartile range [IQR], 6–11) versus nine (IQR, 7–12). The geographically separate units providing HDC had a median number of beds of eight (IQR, 4–14), with a median ratio of separate HDC beds to total beds in the primary unit of 1.0 (IQR, 0.5–1.5). Physician staffing varied for the geographically separate units: 15 (36.6%) were covered by critical care physicians, 16 (39.0%) were covered by noncritical care physicians, and eight (19.5%) had a joint (critical care/

noncritical care) staffing model. Staffing for two (4.9%) was unknown.

Patients

A total of 64,064 patients were admitted to a primary critical care unit and received Level 3 IC in the first 24 hours after admission and subsequently received Level 2 HDC (see Figure E1). Of these, 15,050 (23.5%) patients were admitted to a primary unit with dual HDC (Table 2). Source of admission to the primary unit varied, with fewer patients admitted directly from the acute hospital ward in primary units with dual HDC (19.4% vs. 28.8%) (Table 2) and there were some differences in primary reason for admission (diagnostic category) (Table 2). The median length of Level 3 care was the same (3 d; IQR, 2–7) for both groups. Primary critical care unit length of stay was shorter for patients cared for in primary units with dual HDC (3.8 [1.9–8.4] vs. 4.7 [2.4–9.9] d for integrated HDC). For patients admitted to primary units with dual HDC who survived to ICU discharge, 55.1% were discharged directly to the geographically separate HDC unit (vs. directly to the hospital ward). For details of the case mix of the patients discharged from the primary units with dual HDC directly to a geographically separate HDC unit versus those discharged directly to the ward, see Table E1.

Table 1. Characteristics of Acute Hospitals and Primary Critical Care Units with Integrated or Dual High-Dependency Care

	Integrated HDC	Dual HDC
Number of hospitals/critical care units, n (%)	151 (78.6)	41 (21.4)
Hospital type, n (%)		
University	36 (23.8)	14 (34.2)
University affiliated	24 (16.0)	5 (12.2)
Nonuniversity	91 (60.3)	22 (53.7)
Number of beds in primary critical care unit, median (IQR)	9 (7–12)	8 (6–11)
Number of beds in geographically separate HDU, median (IQR)	NA	8 (4–14)
Ratio of beds in geographically separate HDU to primary critical care unit, median (IQR)	NA	1.0 (0.5–1.5)
Staffing of geographically separate HDU, number of units (%)		
Critical care physicians	NA	15 (36.6)
Noncritical care physicians	NA	16 (39.0)
Joint model	NA	8 (19.5)
Unknown	NA	4 (4.9)

Definition of abbreviations: HDC = high-dependency care; HDU = high-dependency unit; IQR = interquartile range; NA = not applicable.

Table 2. Case Mix of Admissions (Those Receiving Level 3 Intensive Care in the First 24 Hours after Admission and Subsequently Receiving Level 2 High-Dependency Care) to Primary Critical Care Units with Integrated or Dual High-Dependency Care

Admissions to Primary Critical Care Unit	Integrated HDC	Dual HDC
Number of admissions	49,014	15,050
Age, mean $\pm$ SD	61.5 $\pm$ 17.1	58.8 $\pm$ 18.1
Sex, % male	56.6	59.0
Source of admission, %		
Emergency department	25.5	28.4
Ward	28.8	19.4
Operating room	42.8	48.5
Other	3.0	3.7
Type of admission, %		
Medical (nonsurgical)	59.1	54.5
Elective surgical	14.8	11.9
Emergency surgical	26.2	33.6
APACHE II severe chronic health conditions (any), %	15.8	11.9
CPR in 24 h prior to admission, %	7.6	8.8
Length of prior acute hospital stay, median (IQR)	1 (0–2)	1 (0–2)
MV at any time during stay, %	87.0	91.4
Primary reason for admission, organ system category, %		
Respiratory	22.6	20.1
Cardiovascular	16.1	19.0
Gastrointestinal	29.3	24.9
Neurologic	12.6	18.6
Genitourinary	8.9	7.2
Endocrine/metabolic	5.8	5.8
Other	4.8	4.4
US APACHE II score, median (IQR)	17 (13–21)	16 (12–20)
UK APACHE II probability of acute hospital mortality, median (IQR)	22.5 (11.8–38.2)	20.7 (10.9–36.1)
2011 ICNARC physiology score, median (IQR)	19 (14–25)	19 (14–25)
2011 ICNARC probability of acute hospital mortality, median (IQR)	22.8 (8.2–45.1)	21.4 (8.0–43.2)
Primary critical care unit length of stay, d, median (IQR)	4.7 (2.4–9.9)	3.8 (1.9–8.4)
Level 3 intensive care days in primary unit, median (IQR)*	3 (2–7)	3 (2–7)
Level 2 HDC days in primary unit, median (IQR)*	2 (1–4)	1 (1–2)
Discharged to geographically separate HDU, %	NA	52.4
Discharged to geographically separate HDU (of those alive at discharge from primary unit), %	NA	55.1

Definition of abbreviations: APACHE II = Acute Physiology and Chronic Health Evaluation II; CPR = cardiopulmonary resuscitation; HDC = high-dependency care; HDU = high-dependency unit; ICNARC = Intensive Care National Audit & Research Centre; IQR = interquartile range; MV = mechanical ventilation; NA = not applicable.

*Excludes one unit because of lack of data collection for these variables.

For primary critical care units with dual HDC, we determined the relationship between the number of beds in the geographically separate unit and actual utilization, defined as the proportion of patients discharged for HDC directly to the geographically separate unit (Figure 1). There was moderate correlation between

the two measures (Spearman correlation, 0.37; $P = 0.017$).

Hospital Mortality

After adjusting for case mix and accounting for clustering by ICU, overall acute hospital mortality was no different for patients cared for in primary critical

care units with dual HDC compared with integrated HDC (16.2% vs. 19.0%; adjusted odds ratios, 0.94 [0.86–1.03]; $P = 0.16$) (Table 3). There was no dose response when stratified into tertiles based on the percentage of patients actually discharged for HDC directly to the geographically separate unit (Table 3). When physician staffing of the geographically separate units was examined, there was no difference in case mix adjusted acute hospital mortality for patients cared for in primary units with dual HDC when the provision of HDC in the geographically separate unit was by either critical care or noncritical care staff; there was lower adjusted acute hospital mortality when the provision of HDC in the geographically separate unit was a joint staffing model (likelihood ratio test of differences between categories, $P = 0.025$) (Table 3).

Patient Flow

The total duration of critical care (summing days in both the primary unit and the geographically separate unit, where relevant) was longer for patients cared for in primary units with dual HDC (median, 7 [4–13] vs. 6 [3–11] d; adjusted relative difference, 1.09 [1.03–1.16]; $P = 0.002$). Total acute hospital length of stay did not differ, nor did estimates of the overall costs of critical care, after risk-adjustment (Table 4).

Patients who survived to discharge from the primary critical care unit were more likely to be discharged at night from primary units with dual HDC, using both the narrower and broader definition for night (Table 4), and were more likely to be readmitted to the primary unit. Delay in discharge from the primary unit, defined as receiving any Level 1 or Level 0 care while still in the primary unit, was less frequent in hospitals providing dual HDC.

When primary critical care units with dual HDC were grouped into tertiles by the proportion of discharges for HDC directly to the geographically separate unit, the increase in total duration of critical care showed a step-wise increase with increasing use of HDC beds (Table 5). Costs of critical care were not increased in any tertile. The increased likelihood of discharge at night was also associated with increasing use of the geographically separate unit, but there was no statistically significant difference

Figure 1. Correlation between ratio of number of beds for HDC in the geographically separate unit and number of beds in the primary critical care unit, and proportion of patients discharged for HDC from the primary critical care unit to the separate unit. HDC = high-dependency care.

between the tertiles (likelihood ratio test, $P = 0.12$).

Discussion

We have shown that provision and use of HDC in geographically separate units was not associated with any difference in acute hospital mortality for critically ill adult patients. Provision and use of HDC in geographically separate units was associated with a decrease in likelihood of a delay in

discharge from the primary unit. This potential advantage, however, must be weighed against potential disadvantages; we found that provision and use of HDC in geographically separate units was associated with an increase in overall duration of critical care and a greater likelihood of discharge out of the primary unit at night.

Decreasing transitions and reducing duration of critical care are important goals in the era of cost-containment with a focus on patient-centered experience. In the past, such experiences as discharge from

an ICU at night to a general ward have been shown to be associated with worse outcomes for patients (11). Overall, having more discharges at night in our study was not associated with an increase in hospital mortality for all patients, presumably because patients were often being “safely” transitioned to HDC. However, such movement of patients may not be ideal from a patient experience perspective.

We did find that one staffing model for HDC in a geographically separate unit (combined critical care/noncritical care staffing) was associated with a decrease in hospital mortality compared with integrated HDC. This finding is of questionable significance, but does fit with the idea that multidisciplinary care may be beneficial within critical care (15). The role of specialists (e.g., intensivists) in the care of patients transitioning from IC to HDC and the optimal staffing for this level of care warrants further study.

Our study differs from previous studies on the provision and impact of HDC in several ways. First, most previous studies were single center, usually assessing outcomes or costs in a before-after design (4–7). Second, these studies have generally focused on the impact of introducing (or reducing) HDC beds, rather than in a steady-state system. Overall, data from previous studies are inconclusive regarding the impact of dual or integrated HDC on

Table 3. Adjusted Acute Hospital Mortality for Admissions (Those Receiving Level 3 Intensive Care in the First 24 Hours after Admission and Subsequently Receiving Level 2 High-Dependency Care) to Primary Critical Care Units with Integrated or Dual High-Dependency Care

Admissions to Primary Critical Care Unit	N	Acute Hospital Mortality (%)	Adjusted Odds Ratio*	95% CI	P Value
Integrated HDC	49,014	19.0	Ref	—	—
Dual HDC	15,050	16.2	0.94	0.86–1.03	0.16
Tertile of dual HDC hospitals based on percentage of patients discharged from primary critical care unit directly to geographically separate HDU					
Tertile 1 (1.0–39.9%)	3,948	17.3	0.83	0.71–0.97	0.017
Tertile 2 (40.0–63.6%)	4,487	14.4	0.96	0.82–1.12	0.59
Tertile 3 (63.7–99.0%)	6,615	16.7	1.00	0.88–1.14	0.98 [†]
Staffing of geographically separate HDUs [‡]					
Critical care physicians	3,197	18.5	1.06	0.93–1.22	0.39
Noncritical care physicians	5,052	15.2	0.88	0.78–1.00	0.054
Combination	3,517	14.3	0.81	0.68–0.96	0.016 [§]

Definition of abbreviations: CI = confidence interval; HDC = high-dependency care; HDU = high-dependency unit; ICU = intensive care unit.

*Adjusted for Intensive Care National Audit & Research Centre score, source of admission to ICU, cardiopulmonary resuscitation in the 24 h prior to ICU admission, age and type of hospital with ICU as a random effect.

[†]Likelihood ratio test for differences between groups, $P > 0.05$.

[‡]Excludes two units with unknown staffing information.

[§]Likelihood ratio test for differences between groups, $P = 0.025$.

Table 4. Resource Use and Costs for Admissions (Those Receiving Level 3 Intensive Care in the First 24 Hours after Admission and Subsequently Receiving Level 2 High-Dependency Care) to Primary Critical Care Units with Integrated or Dual High-Dependency Care

	Integrated HDC	Dual HDC	P Value	Adjusted Relative Difference (Dual HDC Compared with Integrated HDC)	95% CI	P Value
All admissions to primary critical care unit	n = 49,014	n = 15,050				
Total duration of critical care, median (IQR)*	6 (3 to 11)	7 (4 to 13)	<0.001	1.09	1.03 to 1.16	0.002
Total acute hospital length of stay, d, median (IQR)	19 (10 to 36)	21 (11 to 41)	<0.001	1.06	1.00 to 1.12	0.056
Total costs of critical care, mean pounds sterling $\pm$ SD*	11,221 $\pm$ 13,658	12,217 $\pm$ 14,290	<0.001	Adjusted Mean Difference 382	−438 to 1,201	0.36
All survivors of primary critical care unit	n = 44,431	n = 11,513		Adjusted Odds Ratio		
Discharges at night (0:00 to 4:59), %	3.0	6.1	<0.001	2.25	1.75 to 2.89	<0.001
Discharges at night (22:00 to 06:59), %	8.1	14.5	<0.001	2.05	1.64 to 2.57	<0.001
Readmissions to primary critical care unit, %	5.7	6.9	<0.001	1.22	1.08 to 1.38	0.002
Delayed discharge from primary critical care unit, %	19.9	10.8	<0.001	0.51	0.30 to 0.88	0.015

Definition of abbreviations: CI = confidence interval; HDC = high-dependency care; IQR = interquartile range.

*Excludes one unit because of lack of data collection for these variables. Includes Level 3 intensive care and Level 2 HDC days in primary and separate units, where relevant.

All analyses adjusted for the components of the Intensive Care National Audit & Research Centre score.

mortality, patient flow, or the costs of care (16, 17). In comparison, we looked at an established system of care, allowing for the fact that many units already incorporated HDC into their units in the United Kingdom and avoided the biases associated with either a before-after study design or different patient selection for discharge to HDC beds and floor beds. We examined the costs of delivery of critical care by assigning previously derived costs for care at each level, but chose not to assess further the economic impact of the decision to maintain HDC in geographically separate units, because of the complexity of this issue (18).

The primary strengths of this study include the high quality of the clinical data, which are collected prospectively by trained data collectors, and the national representativeness of the sample of hospitals and critically ill patients. The relative homogeneity of staffing models and hospital structure in UK hospitals allows for robust comparisons across hospitals and estimates of the impact of different organization and provision of care.

One limitation of our study is that, although we attempted to create appropriately comparable groups of patients

by restricting our cohort to only those who received both Level 3 and Level 2 care, we may have created new biases in the patient groups. However, we found that our groups received the same amount of Level 3 care, with similar severity of illness, suggesting that we were examining comparable cohorts of patients. Moreover, most (60%) patients excluded because they did not receive Level 2 care died in the ICU. Other limitations of our study include potential biases caused by other differences in either the hospital structure and/or the staffing in hospitals that do or do not have separate HDC, particularly with regard to staffing on hospital wards. We were able to collect information on staffing models for HDC in all but two of the hospitals providing separate HDC, demonstrating a range of staffing models. We also chose to treat all hospitals with integrated HDC as one group; many of these units have designated HDC beds colocated with IC beds, whereas others operate primarily as IC beds with no formal provision of HDC. However, without provision of HDC in a separate unit in the hospital, we hypothesized that these units *must* provide HDC for their patients within the confines of their primary critical care unit. This hypothesis

was born out by the longer time spent in Level 2 care in the primary unit for patients cared for in units with integrated HDC.

Although we were able to confirm the number of separate beds for HDC in hospitals, we could not determine the relative availability of those beds for patients ready for discharge from the primary critical care unit. We chose to use the percentage of patients discharged for HDC from the primary unit as a marker of availability, because we believed that this was the most relevant measure. We also demonstrated a reasonable correlation between the ratio of separate HDC beds to beds in the primary critical care unit and their use. We could not assess the impact of HDC in geographically separate units on care of patients in the hospital who never required Level 3 IC. It is possible that patients cared for elsewhere in the hospital may gain benefit through access to those beds for higher-level monitoring and care (19, 20). We were also unable to assess the impact of shorter duration of stay in primary units on the overall availability of beds for critically ill patients and the likelihood of timely versus delayed admission for other patients requiring care.

Table 5. Resource Use and Costs for Admissions (Those Receiving Level 3 Intensive Care in the First 24 Hours following Admission and Subsequently Receiving Level 2 High-Dependency Care) to Primary Critical Care Units with Integrated or Dual-High Dependency Care Stratified by Tertile of Proportion of Discharges for High-Dependency Care to the Geographically Separate Unit

	Comparison with Admissions to Primary Critical Care Units with Integrated HDC					
	Tertile 1 (1.0–39.9%)		Tertile 2 (40.0–63.6%)		Tertile 3 (63.7–99.0%)	
	Adjusted Relative Difference (95% CI)	P Value	Adjusted Relative Difference (95% CI)	P Value	Adjusted Relative Difference (95% CI)	P Value (for Comparison with Integrated HDC)
Total duration of critical care, d	0.95 (0.86 to 1.04)	0.27	1.12 (1.02 to 1.23)	0.02	1.18 (1.09 to 1.28)	<0.001
Total acute hospital length of stay, d	0.93 (0.84 to 1.02)	0.11	1.08 (0.99 to 1.18)	0.096	1.03 (0.95 to 1.11)	0.51
						<0.001 0.05
	Adjusted Mean Difference	P Value	Adjusted Mean Difference	P Value	Adjusted Mean Difference	P Value
Total costs of critical care, pounds sterling [†]	–1,135 (–2,516 to 245)	0.11	889 (–492 to 2,271)	0.21	1,085 (–89 to 2,260)	0.07
						0.03
All Survivors of Primary Critical Care Unit	Adjusted OR	P Value	Adjusted OR	P Value	Adjusted OR	P Value
Discharges at night (0:00 to 4:59)	1.54 (0.99 to 2.38)	0.054	2.59 (1.73 to 3.89)	<0.001	2.55 (1.81 to 3.61)	<0.001
Discharges at night (22:00 to 06:59)	1.45 (0.98 to 2.15)	0.060	2.29 (1.58 to 3.31)	<0.001	2.35 (1.71 to 3.22)	<0.001
Readmissions to the primary critical care unit, %	1.11 (0.89 to 1.38)	0.36	1.16 (0.95 to 1.43)	0.15	1.32 (1.12 to 15.6)	0.001
Delayed discharge from primary critical care unit	1.02 (0.40 to 2.60)	0.96	0.45 (0.18 to 1.12)	0.09	0.35 (0.16 to 0.76)	0.008
						0.18

Definition of abbreviations: CI = confidence interval; HDC = high-dependency care; OR = odds ratio.

*Wald test for linear outcomes, likelihood ratio test for binary outcomes.

[†]Level 3 intensive care and Level 2 HDC days in primary and separate units, where relevant.

Finally, these findings may not be generalizable to hospitals in other healthcare systems in other countries (21). In particular, HDC in the UK NHS is theoretically staffed with a ratio of one nurse to two patients, which may be closer to the nurse to patient ratio for IC in some other countries, such as the United States (22, 23). The UK NHS is also a healthcare system with a relative under-provision of IC beds compared with many other developed countries (24). Therefore, the impact of the provision of HDC in geographically separate units may be different in healthcare systems with higher overall supply of IC and more patients admitted to IC for monitoring rather than acute organ support (21, 25). However, the role of

HDC in a hospital, namely to provide a level of care between IC and general ward care, is well recognized across many healthcare systems and countries. Moreover, the questions of their overall utility and how to staff these beds are universal (1, 2, 26).

The concept of “cohorting” patients requiring similar levels of care to focus resources and attention was a large part of the development of IC (27). This model naturally led to the need to transfer a patient out of a unit when no longer requiring IC. However, as patient complexity has increased, and with the development of chronic critical illness as an entity (28), care transitions may be more fraught and could ultimately cause harm (29, 30). Many individual

hospitals and systems may wrestle with the question of whether to expand ICUs with additional beds that can deliver HDC, or to create separate units. These data suggest that both systems provide adequate critical care, with trade-offs between the patient experience and efficiency of critical care delivery. Further work is needed to identify optimal staffing models for patients requiring HDC. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

Acknowledgment: The authors thank the Case Mix Programme Team at Intensive Care National Audit and Research Centre for their assistance with these data.

References

- Boots R, Lipman J. High dependency units: issues to consider in their planning. *Anaesth Intensive Care* 2002;30:348–354.
- Corrado A, Roussos C, Ambrosino N, Confalonieri M, Cuvelier A, Elliott M, Ferrer M, Gorini M, Gurkan O, Muir JF, et al.; European Respiratory Society Task Force on epidemiology of respiratory intermediate care in Europe. Respiratory intermediate care units: a European survey. *Eur Respir J* 2002;20:1343–1350.
- Prin M, Wunsch H. The role of stepdown beds in hospital care. *Am J Respir Crit Care Med* 2014;190:1210–1216.
- Eachempati SR, Hydo LJ, Barie PS. The effect of an intermediate care unit on the demographics and outcomes of a surgical intensive care unit population. *Arch Surg* 2004;139:315–319.
- Fox AJ, Owen-Smith O, Spiers P. The immediate impact of opening an adult high dependency unit on intensive care unit occupancy. *Anaesthesia* 1999;54:280–283.
- McIlroy DR, Coleman BD, Myles PS. Outcomes following a shortage of high dependency unit beds for surgical patients. *Anaesth Intensive Care* 2006;34:457–463.
- Solberg BC, Dirksen CD, Nieman FH, van Merode G, Poeze M, Ramsay G. Changes in hospital costs after introducing an intermediate care unit: a comparative observational study. *Crit Care* 2008;12:R68.
- Stelfox HT, Lane D, Boyd JM, Taylor S, Perrier L, Straus S, Zygun D, Zuege DJ. A scoping review of patient discharge from intensive care: opportunities and tools to improve care. *Chest* [online ahead of print] 11 Sept 2014; DOI: 10.1378/chest.13-2965.
- Department of Health. Comprehensive critical care: a review of adult critical care services. UK: Department of Health; 2000.
- Harrison DA, Brady AR, Rowan K. Case mix, outcome and length of stay for admissions to adult, general critical care units in England, Wales and Northern Ireland: the Intensive Care National Audit & Research Centre Case Mix Programme Database. *Crit Care* 2004;8:R99–R111.
- Goldfrad C, Rowan K. Consequences of discharges from intensive care at night. *Lancet* 2000;355:1138–1142.
- Department of Health. 2010–11 Reference costs publication. UK: Department of Health; 2011.
- Thompson SG, Barber JA. How should cost data in pragmatic randomised trials be analysed? *BMJ* 2000;320:1197–1200.
- Harrison DA, Parry GJ, Carpenter JR, Short A, Rowan K. A new risk prediction model for critical care: the Intensive Care National Audit & Research Centre (ICNARC) model. *Crit Care Med* 2007;35:1091–1098.
- Kim MM, Barnato AE, Angus DC, Fleisher LA, Kahn JM. The effect of multidisciplinary care teams on intensive care unit mortality. *Arch Intern Med* 2010;170:369–376.
- Vincent JL, Burchardi H. Do we need intermediate care units? *Intensive Care Med* 1999;25:1345–1349.
- Keenan SP, Massel D, Inman KJ, Sibbald WJ. A systematic review of the cost-effectiveness of noncardiac transitional care units. *Chest* 1998;113:172–177.
- Wunsch H, Gershengorn H, Scales DC. Economics of ICU organization and management. *Crit Care Clin* 2012;28:25–37.
- Joynt GM, Gomersall CD. Is ‘more’ always ‘better’? Moving towards optimal utilization of high dependency and intensive care beds by selecting the right patients for admission. *Anaesth Intensive Care* 2006;34:423–425.
- Wunsch H. Is there a Starling curve for intensive care? *Chest* 2012;141:1393–1399.
- Wunsch H, Angus DC, Harrison DA, Linde-Zwirble WT, Rowan KM. Comparison of medical admissions to intensive care units in the United States and United Kingdom. *Am J Respir Crit Care Med* 2011;183:1666–1673.
- Dimick JB, Swoboda SM, Pronovost PJ, Lipsett PA. Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and resource use after hepatectomy. *Am J Crit Care* 2001;10:376–382.
- West E, Mays N, Rafferty AM, Rowan K, Sanderson C. Nursing resources and patient outcomes in intensive care: a systematic review of the literature. *Int J Nurs Stud* 2009;46:993–1011.
- Wunsch H, Angus DC, Harrison DA, Collange O, Fowler R, Hoste EA, de Keizer NF, Kersten A, Linde-Zwirble WT, Sandiumenge A, et al. Variation in critical care services across North America and Western Europe. *Crit Care Med* 2008;36:2787–2793, e1–e9.
- Zimmerman JE, Kramer AA. A model for identifying patients who may not need intensive care unit admission. *J Crit Care* 2010;25:205–213.
- Fineberg HV, Scadden D, Goldman L. Care of patients with a low probability of acute myocardial infarction. Cost effectiveness of alternatives to coronary-care-unit admission. *N Engl J Med* 1984;310:1301–1307.
- Berthelsen PG, Cronqvist M. The first intensive care unit in the world: Copenhagen 1953. *Acta Anaesthesiol Scand* 2003;47:1190–1195.
- Nelson JE, Cox CE, Hope AA, Carson SS. Chronic critical illness. *Am J Respir Crit Care Med* 2010;182:446–454.
- Bell CM, Brener SS, Gunraj N, Huo C, Bierman AS, Scales DC, Bajcar J, Zwarenstein M, Urbach DR. Association of ICU or hospital admission with unintentional discontinuation of medications for chronic diseases. *JAMA* 2011;306:840–847.
- Horwitz LI, Meredith T, Schuur JD, Shah NR, Kulkarni RG, Jenq GY. Dropping the baton: a qualitative analysis of failures during the transition from emergency department to inpatient care. *Ann Emerg Med* 2009;53:701–710, e4.