The coronavirus disease 2019 (COVID-19) outbreak in New York State (NYS) has put substantial strain on critical care resources such as intensive care unit (ICU) beds and mechanical ventilation capacity. In response, state authorities suspended all elective surgeries in mid-March of 2020 to increase hospital (and ICU) bed capacity. The potential impact of canceling elective surgery on ICU capacity is unclear.

**BACKGROUND:** In response to the coronavirus disease 2019 (COVID-19) pandemic, New York State ordered the suspension of all elective surgeries to increase intensive care unit (ICU) bed capacity. Yet the potential impact of suspending elective surgery on ICU bed capacity is unclear.

**METHODS:** We retrospectively reviewed 5 years of New York State data on ICU usage. Descriptions of ICU utilization and mechanical ventilation were stratified by admission type (elective surgery, emergent/urgent/truma surgery, and medical admissions) and by geographic location (New York metropolitan region versus the rest of New York State). Data are presented as absolute numbers and percentages and all adult and pediatric ICU patients were included.

**RESULTS:** Overall, ICU admissions in New York State were seen in 10.1% of all hospitalizations (n = 1,232,986/n = 12,251,617) and remained stable over a 5-year period from 2011 to 2015. Among n = 1,232,986 ICU stays, sources of ICU admission included elective surgery (13.4%, n = 165,365), emergent/urgent admissions/trauma surgery (28.0%, n = 345,094), and medical admissions (58.6%, n = 722,527). Ventilator utilization was seen in 26.3% (n = 323,789/n = 1,232,986) of all ICU patients of which 6.4% (n = 20,652), 32.8% (n = 106,186), and 60.8% (n = 196,951) was for patients from elective, emergent, and medical admissions, respectively. New York City holds the majority of ICU bed capacity (70.0%; n = 2496/n = 3566) in New York State.

**CONCLUSIONS:** Patients undergoing elective surgery comprised a small fraction of ICU bed and mechanical ventilation use in New York State. Suspension of elective surgeries in response to the COVID-19 pandemic may thus have a minor impact on ICU capacity when compared to other sources of ICU admission such as emergent/urgent admissions/trauma surgery and medical admissions. More study is needed to better understand how best to maximize ICU capacity for pandemics requiring heavy use of critical care resources. (Anesth Analg XXX;XXX:00–00)
ICU bed and ventilator capacity, however, is not well studied.

We reviewed New York Statewide Planning and Research Cooperative System (SPARCS) data from 2011 to 2015 to estimate the effect of statewide suspension of elective surgeries on ICU bed and ventilator usage. To assess the potential impact on New York City (NYC), we evaluated how NYC—the current epicenter of the COVID-19 outbreak—related to the rest of NYS with respect to changes in elective surgery and ICU/ventilator capacity.

METHODS
This study was approved by the institutional review board of Hospital for Special Surgery (2016-436). The requirement for written informed consent was waived given the deidentified nature of the data. Patient-level data were extracted from the New York SPARCS dataset (2011–2015), which includes patient-level and billing data for all inpatient and outpatient visits in NYS. We included all adult and pediatric ICU admissions and excluded cases classified as “newborn” or “neonatal” ICU admissions, those with missing date of admission, and patients with HIV infection or who had an abortion (due to withholding of data on these patients by NYS).

Data Source and Patient Selection
ICU and mechanical ventilation were defined using ICU-specific billing codes and International Classification of Diseases, Ninth Edition (ICD-9) codes 93.9x and 96.7x. Mechanical ventilation was further classified into invasive/noninvasive and duration (≥96 and <96 hours of consecutive invasive ventilation). The source of ICU admission was categorized as (1) elective surgery, (2) emergent/urgent/trauma surgery admissions, and (3) medical admissions. Surgical/medical cases were differentiated based on ICD-9-clinical modifications surgical flag software. Type of admission (elective, emergent, trauma, and urgent) is a variable coded in the SPARCS database. Additional study variables included geographic region (NYC metropolitan area—defined as NYC, Long Island, and the mid- and lower Hudson Valley counties—compared to the rest of NYS) and year. NYS hospital-level data included the number of ICU beds by hospital (categorized by small, 1–5 beds/medium, 6–15 beds/large, 16–30 beds/very large, >30 beds), and types of ICU. Overall, 157 NYS hospitals have a permanent ICU representing a total number of 4266 ICU beds (700 reserved for neonates, 380 pediatric, and 3186 adult ICU beds).

Statistical Analyses
All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC). Results were reported as case number and percentage, stratified by year, source of ICU admission, and geographic region. Because SPARCS does not provide ICU length of stay data, we used the most recent estimate of an average of 3.8 days spent in the ICU, as published by the Society of Critical Care Medicine, to estimate annual total ICU days in this pre–COVID-19 period (across 3566 pediatric and adult ICUs). As a sensitivity analysis, we also calculated a range of 20% shorter or longer average ICU length of stay. Number of total ICU days was subgrouped by source of admission to allow for a theoretical estimation of the number of COVID-19–related ICU stays to be gained with the elimination of ICU days related to elective surgery. An ICU length of stay of 10.5 days was applied for this estimation based on data from California and Washington State.

RESULTS
A total of 1,235,517 ICU admissions were identified from 2011 to 2015 in NYS. N = 693 cases were excluded because of missing inpatient admission date, and 1838 newborn cases were excluded. For our analysis, 1,232,986 cases were included, averaging 246,597 (n = 1,232,986/5) per year. This represented 10.1% of total hospital admissions over the study period (n = 1,232,986/n = 12,251,617) which remained stable over time (Figure). Average ICU occupancy rate was 72.0% (with a range of 57.6%–86.4% using a 20% variation in assumed average ICU length of stay). Overall, 13.4% of ICU admissions were attributed to elective surgery, versus 28.0% for emergent/urgent/trauma surgery and 58.6% for medical reasons (Table 1). Total number of ICU days decreased from 132,552 in 2011 to 101,996 in 2015, representing theoretical capacity of 101,996/10.5 = 9714 (809 monthly) COVID-19–related ICU stays. A similar decrease was observed for ICU admissions related to emergent/urgent/trauma surgery (theoretical capacity of 211,569/10.5 = 20,149 COVID-19–related ICU stays in 2015) while an increase was observed for medical ICU admissions (theoretical capacity of 635,531/10.5 = 60,527 COVID-19–related ICU stays, applying estimates from 2015).

Among all ICU admissions, 26.3% (n = 323,789/n = 1,232,986) of patients required mechanical ventilation. The majority (60.8%) of ventilated patients were medical ICU admissions while 6.4% represented patients admitted to the ICU after elective surgery. Emergent/urgent/trauma surgery–related ICU admissions were most likely (51.2%) to require prolonged (ie, ≥96 hours) of invasive ventilation (Table 2).

NYC had twice as many ICU beds and admissions as the rest of NYS (Table 3). Of all ventilated patients in NYS, 70.0% were located in the NYC metropolitan area. This imbalance in ICU volume and use of mechanical ventilation was particularly evident for emergent/urgent/trauma surgery–related
ICU admissions (n = 247,998 in NYC compared to n = 97,096 admissions in NYS) and the number of high ICU volume hospitals. In NYC, 221,970 patients required an ICU stay with mechanical ventilation (Table 3); 12,726 of those patients were admitted after elective surgery (12,726/221,970 = 5.7%), versus emergent/urgent/trauma surgery (n = 75,334) and medical reasons (n=133,910). In comparison, in NYS, 7.8% (7926/101,067) of patients required mechanical ventilation in the ICU.

**DISCUSSION**

In this 5-year retrospective review of the New York SPARCS database, we found that only 13% of ICU admissions represented an admission after elective surgery. In contrast, more than twice as many patients requiring an ICU were admitted after emergent/urgent/trauma surgery while the bulk of ICU admissions were for medical reasons. Elective surgeries played an even smaller role (6%) in terms of mechanical ventilation requirements while this was 33% and 61% for ICU admissions related to emergent/urgent/trauma surgery and medical reasons, respectively. The NYC metropolitan region holds the majority of critical care capacity in NYS.

Our data are generally consistent with prior studies of ICU resource use due to elective surgery. Two 2018 studies of ICU use after noncardiac surgery found that elective surgery cases only consumed 13.4% of ICU resources and 6.4% of ventilator requirements.6,7
This assessment of a relatively minor impact is compounded by the relatively small share of patients after elective surgery that require prolonged ventilation—thus suggesting a shorter ICU length of stay—when compared to patients admitted to the ICU for emergent/urgent/trauma surgery or medical etiologies. A 2000 study of 2 surgical ICUs also observed that stays after elective surgery rarely were for extended periods while ICU stays after emergency surgery were more likely to be prolonged.\textsuperscript{8} Our data suggesting requirement of mechanical ventilation in 26.3% of ICU admissions is likewise consistent with previously reported rates ranging from 20.7% to 38.9%.\textsuperscript{9}

Results presented in the current study have potential implications for resource management in crises requiring heavy use of scarce ICU resources. While suspending elective surgeries clearly increases hospital (non-ICU) bed capacity, our analysis suggests a limited impact on ICU resource allocation, especially in the context of the much larger share of ICU admissions due to emergent/urgent/trauma surgery and medical etiologies.

A surge in critical care demand requires an orderly deescalation of less essential services to prevent catastrophic failure of the health care system.\textsuperscript{10} Unfortunately, unlike elective surgery, urgent/emergent/trauma surgery and medical ICU admissions cannot be deescalated. Suspending elective surgery is controllable, but may only free up limited critical care resources. In the context of COVID-19 care, which often requires prolonged courses of mechanical ventilation,\textsuperscript{11} the relatively short duration of ICU stays after elective surgery\textsuperscript{8} suggests that the impact of reducing elective surgery is likely even smaller. Combined, these findings point toward greater use of critical care resources in ICU admissions not linked to elective surgeries.\textsuperscript{11}

Of specific interest is critical care utilization among patients in the emergent/urgent/trauma surgery group as they represent a larger share of surgical admissions when compared to elective surgery. Although data are lacking, we hypothesize that this category of ICU utilization may also be impacted through policies such as stay-at-home orders. Intended to contain the spread of COVID-19, statewide stay-at-home orders may also decrease automobile accidents due to less traffic. Such an effect on traffic accidents\textsuperscript{12,13} has been noted in California after statewide stay-at-home orders. Reducing exposure to traffic is likely to lead to reduced trauma-related emergency department visits and subsequent critical care utilization. Stay-at-home orders may also affect crime-related trauma activity that consumes ICU resources, although existing data suggest mixed effects.\textsuperscript{14} Effects of public health policies on ICU resource availability represent an important knowledge gap in disaster planning policy.

Our data do not address other potential effects of suspending elective surgery. Such a decision may only free up limited ICU resources, but may also release non-ICU hospital beds for COVID-19 patients who do not need critical care. Reallocating such patients may then preserve existing ICU beds. Health care workers previously involved in elective surgery may also

### Table 2. Characteristics of Ventilation Use by Source of ICU Admission (2011–2015 Cohort)

| Source of ICU Admission | Elective Surgery | Emergent/Urgent/Trauma Surgery | Medical | Total |
|-------------------------|------------------|-------------------------------|---------|-------|
| Any ventilation, n (%)  | 20,652 (6.4)     | 106,186 (32.8)               | 196,951 (60.8) | 323,789 |
| Noninvasive             | 9283 (6.8)       | 30,347 (22.2)                | 96,905 (71.0) | 136,535 |
| Invasive                | 13,244 (5.8)     | 89,064 (39.3)                | 124,107 (54.8) | 226,415 |
| Both                    | 1875 (4.7)       | 13,659 (34.2)                | 24,379 (61.1) | 39,913  |
| Invasive ventilation duration, n (%) | | | | |
| ≥96 h consecutively    | 4872 (4.9)       | 50,716 (51.2)                | 43,510 (43.9) | 99,098  |
| <96 h consecutively    | 8357 (6.6)       | 38,287 (31.1)                | 80,505 (63.3) | 127,149 |
| Not defined             | 15 (8.9)         | 61 (36.3)                    | 92 (54.8)     | 168     |

Abbreviation: ICU, intensive care unit.

### Table 3. Critical Care Resource Utilization by Geographic Area: NYC Metropolitan Area Compared to the Rest of New York State

|                    | NYC Metropolitan | Rest of New York State |
|--------------------|------------------|------------------------|
| Total population\textsuperscript{a} | 13,221,319 (68.2) | 6,156,783 (31.8) |
| Total ICU beds     | 2496 (70.0)      | 1070 (30.0)           |
| ICU admissions, n (%) |                 |                        |
| Elective surgery   | 112,972 (68.3)   | 52,393 (31.7)         |
| Emergent/urgent/trauma surgery | 247,998 (71.9) | 97,096 (28.1) |
| Medical            | 480,281 (66.5)   | 242,246 (33.5)        |
| Total              | 841,251 (68.2)   | 391,735 (31.8)        |
| ICU hospital size, n (%) |             |                        |
| Small, 1–5 beds    | 4 (26.7)         | 11 (73.3)             |
| Medium, 6–15 beds  | 40 (51.3)        | 38 (48.7)             |
| Large, 16–30 beds  | 24 (75)          | 8 (25)                |
| Very large, >30 beds | 24 (75)       | 8 (25)                |
| Any ventilation use, n (%) |             |                        |
| Elective surgery   | 12,726 (61.6)    | 7926 (38.4)           |
| Emergent/urgent/trauma surgery | 75,334 (71.2) | 30,418 (28.8) |
| Medical            | 133,910 (68.1)   | 62,723 (31.9)         |
| Total              | 221,970 (68.7)   | 101,067 (31.3)        |

Abbreviations: ICU, intensive care unit; NYC, New York City.

\textsuperscript{a}Based on 2010 census data.
be redirected to provide care to pandemic patients. Reports of redirecting surgeons to perform invasive procedures, operation room (OR) teams to position patients in prone position, and nurse anesthetists to manage ventilated ICU patients suggest that health care system resource allocation is extremely complex.15

Our study has limitations. First, data from 2011 to 2015 may not accurately represent current ICU practice and capacity in New York. However, year-on-year data suggests that the ICU capacity in NYS and NYC has remained relatively constant during the study period. Second, we do not estimate the effects of suspending elective surgery on non-ICU beds. Changes in these non-ICU resources may have secondary effects on ICU use. Third, the balance of ICU resource utilization due to different emergent or elective surgery or medical reasons may be seasonal, suggesting that the effect of elective surgery on ICU admissions may vary by time of year.16 For example, better weather may increase the number of emergent/urgent admissions/trauma surgery admissions which would further reduce the relative impact of suspension of elective surgeries in terms of ICU capacity.

In conclusion, we found that, over a 5-year period from 2011 to 2015, ICU admissions from patients after elective surgery in New York is likely to have only a small effect on ICU bed availability. Rather, ICU admissions from urgent/emergent surgery and medical sources comprise the majority of ICU admissions both in NYS and NYC. Our results may be valuable for hospital administrators and disaster planning policymakers to optimize the response to future diseases that require heavy use of critical care.

DISCLOSURES

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