Estimation of the number of general anesthesia cases based on a series of nationwide surveys on Twitter during COVID-19 in Japan: A statistical analysis

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Abstract

Coronavirus disease (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first reported in Wuhan, Hubei, China, and has since spread to more than 200 other countries at the time of writing. In light of this situation, the Japanese Government declared a state of emergency in seven regions of Japan on April 7, 2020 under the provisions of the law. The medical care delivery system has been under pressure. Although various surgical societies have published guidelines on which to base their surgical decisions, it is not clear how general anesthesia has been performed and will be performed in Japan. Social networks such as Twitter are becoming a part of society, as various information is accumulated on the web. One of the services provided by Twitter is a voting function—Twitter Polls—through which anonymous surveys can be conducted. We analyzed the results of a series of surveys on Twitter on the status of operating restrictions using a mathematical model, and public data provided by the Japanese Government were used to estimate the current and future changes in the number of general anesthesia performed in Japan. The number of general anesthesia was estimated as $2.77 \times 10^4$ cases per week on 2 May 2020 and $0.68 \times 10^4$ cases in 24 weeks.
Introduction

Coronavirus (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first reported in Wuhan, Hubei, China, and has since spread to more than 200 other countries around the world at the time of writing[1]. In light of this situation, the Japanese Government declared a state of emergency in seven regions of Japan on April 7, 2020 under the provisions of the law. This declaration was extended to the entire nation on the April 17, 2020. The incidence of pneumonia from COVID-19 is considerably higher than from seasonal influenza, and the number of cases with no identifiable route of infection has increased rapidly [2,3]. The medical care delivery system has been under pressure [4]. Emphasis should be placed on maintaining medical care systems. Although various surgical societies have published guidelines on which to base their surgical decisions [5,6], it is not clear how general anesthesia has been performed and will be performed in Japan.

Social networks such as Twitter are becoming a part of our society, as various information is being accumulated on the web [7]. Twitter (Twitter, Inc.) is headquartered in San Francisco, California, United States, and was launched in July, 2006. One of the services provided is a voting function called Twitter Polls. Using this function, anonymous surveys can be conducted on Twitter [8].
We analyzed the results of a series of surveys conducted on Twitter on the status of operating restrictions using a mathematical model, and public data provided by the Japanese Government were used to estimate the current and future changes in the number of general anesthesia carried out in Japan.

Methods

Twitter Surveys

Using the Twitter account @dajhiroki, Twitter Polls was used to conduct eight 24-hour surveys, which were held approximately one week apart from each other, from March 13, 2020 to May 2, 2020. During this period, the spread of COVID-19 had become a social problem in Japan.

The surveys used the same wording throughout the period, in the form of a choice of one of the following four options:

1. No surgical restrictions
2. Partial restrictions (more than half of the usual)
3. Extensive restrictions (less than half of the usual)
4. No scheduled surgery
Transition of responses to the survey

Let the number of responses to the survey be denoted as \( A_{t,*} = \{a_{t,1}, a_{t,2}, a_{t,3}, a_{t,4}\} \), \( t = \{1, \ldots, T\} \) and the proportion of responses to the survey be the simplex \( \theta_{t,i} \), where \( \sum_{i=1}^{4} \theta_{t,i} = 1 \), \( T = 8 \). The transition probability from the \( i \)th answer to the \((i + 1)\)th answer is defined as \( g_{i \to i+1} \) (Figure 1). The transition is denoted as follows:

\[
\begin{align*}
\Delta \theta_{t,1}/\Delta t &= -g_{1\to2} \theta_{t,1} \\
\Delta \theta_{t,2}/\Delta t &= g_{1\to2} \theta_{t,1} - g_{2\to3} \theta_{t,2} \\
\Delta \theta_{t,3}/\Delta t &= g_{2\to3} \theta_{t,2} - g_{3\to4} \theta_{t,3} \\
\Delta \theta_{t,4}/\Delta t &= g_{3\to4} \theta_{t,3}.
\end{align*}
\]

Parameters were inferred through likelihood function \( L(\theta) \) as

\[
L(\theta) = \sum_{t=1}^{T} \left\{ \frac{(a_{t,1} + a_{t,2} + a_{t,3} + a_{t,4})!}{a_{t,1}! a_{t,2}! a_{t,3}! a_{t,4}!} \prod_{i=1}^{4} \theta_{t,i}^{a_{t,i}} \right\}
\]

where \( \theta \) was the set of parameters.

Figure 1: Transition scheme of the proportion of surveys. (1: green) no surgical restrictions, (2: yellow) partial restrictions, (3: orange) extensive restrictions, and (4: red) no scheduled surgery. \( g_{i \to i+1} \) is the transition probability from answer \( i \) to answer \( i + 1 \).
Estimation of the number of general anesthesia performed in Japan during COVID-19

The restriction rate of the number of general anesthesia, $p_i$, $i = \{1, 2, 3, 4\}$ was assumed for each response of the surveys: (1) no surgical restrictions were almost the same as the past statistics, (2) partial restrictions was about 70% restriction rate compared to the past statistics, (3) extensive restrictions was about 40% restriction rate compared to the past statistics, and (4) no scheduled surgery was about 10% restriction rate compared to the past statistics. Under such assumption, restriction rate for each hospital $h$ at week $t$, $p_{t,i,h}$ was generated from probability distribution as follows;

(1) for no surgical restrictive hospitals, $p_{t,1,h}$ was generated from uniform distribution, $U$, ranging from 0.95 to 1.05.

$$p_{t,1,h} \sim U(0.95, 1.05).$$

(2-4) for restrictive management hospitals, $p_{t,i,h}$, $i = \{2,3,4\}$, was generated from beta distribution, $Beta(\alpha, \beta)$. Their parameters $(\alpha_{t,i,h}, \beta_{t,i,h}), i = \{2,3,4\}$, were defined so that the mean was 0.7, 0.4, 0.1 and the variance was 0.005, respectively (figure 2).

$$p_{t,i,h} \sim Beta(\alpha_{t,i,h}, \beta_{t,i,h}), \ i = \{2,3,4\}.$$
Figure 2: Distribution of the degree of restriction for each response group. The mean percentages of the restrictions were generated from probability distributions. In particular, no surgical restrictions (green) were generated from the uniform distribution \( U(0.95, 1.05) \), partial restrictions (yellow), extensive restrictions (orange), and no scheduled surgery (red) were generated from the beta distribution \( \text{Beta}(\alpha, \beta) \). The set of parameters for beta distribution, \((\alpha, \beta)\), were defined so that the respective means were 0.7, 0.4, and 0.1, and the variances were 0.005.

The number of general anesthesia performed at hospital \( h \) in the \( t \)th week, \( R_{h,t} \), was
generated as follows:

$$R_{h,t} \sim \begin{cases} \text{round} \left( N_h p_{t,1,h} \right) & \text{if } i = 1 \\ \text{Binomial} \left( p_{t,i,h}, N_h \right) & \text{otherwise} \end{cases}$$

where $N_h$ is the reference number of the general anesthesia performed at each hospital (data available from e-stat), $\text{round}$ is a rounding function, and $\text{Binomial}(p, N)$ is a binomial sampling function that performs $N$ Bernoulli trials with probability $p$.

The answer to the survey for each hospital at $t = 1$ was randomly allocated to the $i$th answer according to $\theta_{1,i}$ and its status transitioned to the $(i + 1)$th answer by $g_{i,i+1}$.

For sensitivity analysis, two other scenarios were considered. An optimistic scenario assumed relatively high performance in operating rooms, with an average of 80% for “2. Partial restrictions,” 50% for “3. Extensive restrictions,” and 25% for “4. No scheduled surgery.” A pessimistic scenario assumed extremely low performance, with an average of 50% for “2. Partial restrictions,” 30% for “3. Extensive restrictions,” and 3% for “4. No scheduled surgery.”

Analysis and estimation were performed using Markov chain Monte Carlo methods using the rstan package (version 2.19.3) within the R programing language (version 3.3.4). Point estimates and their statistical uncertainty were presented as posterior medians and their 95% credible intervals (CrIs). The data were obtained from the Japan official statistics portal site (e-stat), a public database in Japan.
From March 13, 2020 to May 2, 2020, survey responses were solicited approximately weekly via a Twitter account (@dajhiroki) in Japanese language, with the number of responses received ranging from 47 to 288 (Supplementary Information S1).

The results of the surveys are presented in Table 1. Prevalence of COVID-19 in Japan during the period of the surveys is presented in Table 2.

Table 1: Results of the Twitter surveys

| questionnaire date | 2020/3/13 | 2020/3/20 | 2020/3/27 | 2020/4/6 | 2020/4/10 | 2020/4/17 | 2020/4/24 | 2020/5/2 |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| number of votes    | 112       | 47        | 73        | 160       | 221       | 232       | 288       | 184       |
| 1. No surgical restrictions | 89%       | 77%       | 82%       | 64%       | 46%       | 27%       | 25%       | 29%       |
| 2. Partially restricted (more than half of the usual) | 5%        | 17%       | 7%        | 23%       | 38%       | 38%       | 38%       | 40%       |
| 3. Extensively restricted (less than half of the usual) | 4%        | 2%        | 4%        | 7%        | 13%       | 27%       | 30%       | 23%       |
| 4. No scheduled surgery | 2%        | 4%        | 7%        | 6%        | 3%        | 8%        | 7%        | 8%        |

The number of infected persons during the same period is shown in Table 2.
Table 2: Prevalence of COVID-19 in Japan during the period of the surveys

(https://www.mhlw.go.jp/stf/)

| tested positive cases (case within 7 days) | 2020/3/13 | 2020/3/20 | 2020/3/27 | 2020/4/6 | 2020/4/10 | 2020/4/17 |
|------------------------------------------|------------|-----------|-----------|----------|----------|----------|
| active cases                             | 659(326)   | 928(233)  | 1349(427) | 3569(1208)| 5246(2425)| 9027(3326)|
| serious cases                            | 520        | 681       | 920       | 2921     | 4641     | 7884     |

From the public database

[https://www.e-stat.go.jp/stat-search/file-download?statInfId=000031565245&fileKind=0], there were 3,501 hospitals that were registered as facilities that provide general anesthesia. Of the 3,311 hospitals that reported the number of general anesthesia, 1,989 performed more than 100 general anesthesia.

From the surveys, the transition of the restrictions of general anesthesia was estimated. The median transition probabilities with 95% credible intervals were $g_{1\rightarrow2}$ (from no restrictions to partial restrictions): 0.165 [0.152, 0.178], $g_{2\rightarrow3}$ (from partial restrictions to extensive restrictions): 0.175 [0.153, 0.199], and $g_{3\rightarrow4}$ (from extensive restrictions to no scheduled surgery): 0.109 [0.079, 0.146] (Figure 3A).

From the survey conducted in the first week (March 13, 2020), 89.2% had no surgical
restrictions, but this proportion decreased to 25.3% in the survey conducted in the eighth week (May 2, 2020). It was estimated that the "no surgical restrictions" group would account for only 0.3%, 24 weeks after the final survey date (24 weeks post). The proportions of partial restrictions, extensive restrictions, and no scheduled surgeries were, 5.4%, 3.6%, and 1.8% (March 13, 2020), 35.0%, 28.3%, and 11.2% (May 2, 2020), and 1.7%, 12.9%, and 84.9%, 24 weeks post, respectively (Figure 3B).

Figure 3: Estimated parameters. (A) Transition probability. The violinplot shows the distribution of the posterior probability of $g$. (B) Transition of the proportion of responses to the survey. The transition probability $g$ was fitted to the data $t = \{1, 2, \ldots, T\}$, $T = 8$, and its transition was estimated at 24 weeks.

The median proportions are shown with 95% credible intervals.

The number of general anesthesia performed decreased as the restrictions increased.
Before COVID-19, $4.45 \times 10^4$ cases of general anesthesia were performed per week in Japan. The number of general anesthesia ($10^4$ per week unit) was estimated to be 4.21 [95% CrI: 4.16, 4.26] in the first week survey (March 13, 2020), 2.77 [2.65, 2.90] in the eighth week survey (May 2, 2020), 2.21 [1.97, 2.27] 4 weeks post, and 0.58 [0.68, 0.81] 24 weeks post (Table 3).

![Figure 4](https://example.com/figure4.png)

Figure 4: Estimation of the number of general anesthesia in Japan from the survey results. The green violinplot shows the estimated number of general anesthesia performed during the period of the surveys, and the yellow violinplot shows the estimated number of general anesthesia after the period of the surveys. The violinplots show the distribution of the estimated number of general anesthesia performed at 1,989 hospitals in Japan.
Table 3: Estimated number of general anesthesia ($10^4$ cases per week) in Japan during the period of the surveys and 4, 8 and 24 weeks after the period of the surveys.

Sensitivity analysis showed that the number of general anesthesia performed decreased according to the intensity of the restrictions. From the first week survey (March 13, 2020), the optimistic scenario had a median of $4.26*10^4$ /week, while the pessimistic scenario had a median of 4.14. From the eighth week survey (May 2, 2020), the optimistic scenario median was 3.13, while that of the pessimistic scenario was 2.30. At 24 weeks after the period of the surveys, the optimistic scenario had twice as many cases (1.31) as the setting in this study (0.68), and the pessimistic scenario had twice as few cases (0.34) as the setting in this study.
Figure 5: Estimation of the number of general anesthesia in Japan from the results of the surveys for the three scenarios as a sensitivity analysis. The vertical bars show the 95% credible intervals.

Discussion

It is difficult to adequately control for the level of limitation of usual surgical care during the expansion of COVID-19. It is determined by adherence to official guidelines, restrictions on medical supplies and medical staff, and the level of need for surgery. Still, because circumstances can change quickly, it is often determined by reference to the extent of restrictions at a medical facility other than the home facility.

The staged approach—recommended by the Centers for Medicare and Medicaid Services (CMS) and the American College of Surgeons (ACS)—is used as a guide to determine how to perform surgery in situations where the preservation of ventilators and
personal protective equipment is necessary, and the ICU has been compromised—or is expected to be compromised soon.

The number of respondents to our surveys increased over time, and it is thought that the number of respondents is dependent on their training in knowing the status of operational limitations. By using a series of surveys conducted through Twitter Polls, we were able to quickly determine the extent of the restrictions on surgery at medical facilities across the country. By periodically soliciting responses to the same survey on Twitter, we were able to estimate the extent to which operations would be restricted nationally—over time.

Our methodology in this study is an estimation method that uses mathematical analysis. In this study, we used public data from a database operated by the Japanese Government. The number of hospitals accredited by the Japanese Society of Anesthesiologists (JSA) is about 1,400. However, in this study, 1,989 hospitals that perform at least 100 surgeries per year under general anesthesia were used. The number of operations performed at each hospital varies—mainly according to the size of the hospital. On the other hand, since neither the size of the hospitals to which the survey respondents belonged nor the changes in the number of operations were known, we used mathematical analysis to calculate the number of operations.
This study has several limitations.

In this study, we used a database of the number of general anesthetic procedures. If the number of surgeries performed under local anesthetic was increasing due to COVID-19, we cannot deny the possibility of discrepancies with the actual number of operations.

The number and type of survey responses is a potential limitation.

It is possible that the number of anesthesiologists using Twitter was not sufficient, and there may be some kind of bias in terms of the responses from those that do use it.

Responses were low initially, with 47 in the early stages of the period of the surveys, but increased to 288 in the latter half of the period of the surveys. The growing penetration of the surveys and increasing familiarity with the issue of operating room restrictions may have contributed to an increase in participation, but this may have been biased.

In this study, we calculated the number of surgeries as 95% to 105% for the criteria: "1. No surgical restrictions," 70% for "2. Partial restrictions," 40% for "3. Extensive restrictions," and 10% for "4. No scheduled surgery." In the sensitivity analysis, two scenarios were assumed, but the number of general anesthesia performed could double or halve in the 24 weeks following the period of the surveys. The transition model did not
assume recovery from the later state to the former state, that is, once a certain hospital
transitioned to state “4. No scheduled surgery,” it could never return to states 1, 2, or 3.
The number of general anesthesia largely depended on the intensity of restrictions of the
"no surgical restrictions" group because this group accounted for a large proportion of the
responses.

Conclusions

In this study, we conducted a series of surveys using Twitter Polls, and performed a
mathematical analysis of the results using a public database on the number of general
anesthetic procedures to estimate the changes in the number of surgeries carried out in
Japan.

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Author contributions

H.D, Y.F, and K.H. conceived and designed the study. Y.F performed the analysis.

H.D, Y.F, and K.H. prepared figures and/or tables and wrote the paper. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information S1

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