Digital Tumor Board Solutions Have Significant Impact on Case Preparation

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abstract

PURPOSE Multidisciplinary tumor boards (TBs) are the gold standard for decision-making in cancer care. Variability in preparation, conduction, and impact is widely reported. The benefit of digital technologies to support TBs is unknown. This study evaluated the impact of the NAVIFY Tumor Board solution (NTB) on TB preparation time across multiple user groups in 4 cancer categories: breast, GI, head and neck (ie, ear, nose, and throat, or ENT), and hemopathology.

METHODS This prospective study evaluated TB preparation time in multiple phases pre- and post-NTB implementation at an academic health care center. TB preparation times were recorded for multiple weeks using a digital time tracker.

RESULTS Preparation times for 59 breast, 61 GI, 36 ENT, and 71 hematopathology cancer TBs comparing a pre-NTB phase to 3 phases of NTB implementation were evaluated between February 2018 and July 2019. NTB resulted in significant reductions in overall preparation time (30%) across 3 TBs pre-NTB compared with the final post-NTB implementation phase. In the breast TB, NTB reduced overall preparation time by 28%, with a 76% decrease in standard deviation (SD). In the GI TB, a 23% reduction in average preparation time was observed for all users, with a 48% decrease in SD. In the ENT TB, a 33% reduction in average preparation time was observed for all users, with a 73% decrease in SD. The hematopathology TB, which was the cocreation partner and initial adopter of the solution, showed variable results.

CONCLUSION This study showed a significant impact of a digital solution on time preparation for TBs across multiple users and different TBs, reflecting the generalizability of the NTB. Adoption of such a solution could improve the efficiency of TBs and have a direct economic impact on hospitals.

JCO Clin Cancer Inform 4:757-768. © 2020 by American Society of Clinical Oncology

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INTRODUCTION

Multidisciplinary tumor boards (TBs) provide an interdisciplinary approach for decision-making in cancer care.1 TBs have existed for 50 years2 and were originally intended to educate health care professionals rather than improve clinical outcomes. In the 1980s, it became clear that a community-driven approach to cancer care positively affected the quality of medical service and clinical outcomes.3 Now, TBs are integral to cancer treatment plans,4 are widely considered the gold standard in cancer care delivery,5 and are often required for best practice accreditation programs (eg, American College of Surgeons).1 Imperative criteria include prospective case review and discussion of management decisions within TBs.1 However, TB preparation is time and labor intensive6 and requires the concerted effort of multiple hospital staff to compile clinically relevant data from a variety of sources and systems, often from different providers.7-9

In health care, health information technology (HIT), including electronic medical records (EMRs), makes care more effective and efficient by supporting clinical decision-making, order entries, and exchange of patient information.10,11 Notwithstanding legal and financial support, cases of EMR usability issues, reduced productivity, and physician burnout have been widely reported.12,13 Recent work has revealed a greater understanding of best practices for conducting TB meetings. However, there is limited knowledge about the resources required to prepare patient cases for discussion. Recently, several digital solutions have been introduced to optimize TB preparation.6,14-16 Yet, to our knowledge, there are no large-scale prospective studies to understand the impact of such solutions on TBs. Several recent publications have examined legacy approaches to TBs to identify unmet needs.
and demonstrated how digital solutions could improve efficiency.\textsuperscript{6,17} The NAVIFY Tumor Board solution (NTB; Roche Molecular Systems, Santa Clara, CA) is a cloud-based workflow product that facilitates TBs by integrating all relevant clinical data into a single source. It assists with preparing, presenting, and documenting information for TBs.\textsuperscript{6} NTB integrates with EMRs and displays aggregated data in a single, holistic patient dashboard for oncology care teams to plan optimal treatments for the patient.\textsuperscript{6} The pilot version of NTB evaluated in Spain reduced TB preparation time among oncologists, pathologists, and radiologists.\textsuperscript{6} This study evaluated the impact of a digital TB solution on preparation time of multiple clinical staff and process standardization for TBs in 4 cancer categories.

**METHODS**

**Study Design**

A prospective cohort study design was used to evaluate preparation time for TBs before and after the implementation of NTB at University of Missouri Health Care Ellis Fischel Cancer Center. The study was reviewed and approved by the local institutional review board research and ethics committee (No. 2005046-QI).

Four TBs were evaluated. The hematopathology TB, which was the cocreation site and initial adopter of NTB, and 3 additional TBs (breast cancer, head and neck cancer (ie, ear, nose, and throat, or ENT), and GI). This study compared preparation time for multiple hospital staff during 4 phases (Fig 1A):

1. Phase 1: Before NTB implementation (pre-NTB).
2. Phase 2: After implementation of manual NTB (no integration with hospital EMR).
3. Phase 3: Initial/partial integration with EMR, followed by pathology report integration.
4. Phase 4: Stable phase after completion of integration.

Within each TB, comparisons were conducted—when data were available—for individual user groups and for all groups combined, as follows (Data Supplement, online only):

1. Phase 1 versus phases 2-4 combined, effects of pre-versus post-NTB.
2. Phase 1 versus phases 3 and 4, pre-NTB effects compared with integrated version.
3. Phase 1 versus phase 4, pre-NTB effects compared with stable integration.
4. Phase 2 versus phases 3 and 4, effects of manual versus integrated.
5. Phase 2 versus phase 4, effects of manual versus stable integration.

**Software**

The manual version of NTB was implemented through a phased rollout to each TB throughout 2018 (Fig 1A). The integration phases involved partial integration with the hospital EMR (early phase 3). This permitted ordering of TB case discussion via EMR and triggered flow of patient information from EMR to NTB. In the initial phase, patient demographic data—including name, age, sex, date of birth, and medical record number—were automatically incorporated. Pathology report integration was introduced on November 7, 2018 (mid/late phase 3) and finalized on April 9, 2019. The phase from April 9 to the end of July 2019 was stable after integration (phase 4). NTB integration is ongoing, with the ultimate objective of full integration of all data sources.

**Time-Tracking and Case Preparation**

All participants prospectively collected their individual TB preparation times for each week, during all phases of NTB implementation, using the time-tracking digital application Toggl (Toggl OÜ, Tallinn, Estonia; Fig 1A).

**Training**

Participants in TB preparation received formal training on the Toggl time-tracking app and both versions of NTB before study initiation.

**Statistical Analysis**

Analysis was carried out using R statistical software (version 3.5.3). A Student’s $t$ test was performed in cases when data
FIG 1. (A) Study design showing detailed timeline of the phased rollout of NAVIFY Tumor Board (NTB) for all tumor boards (TBs). Weekly mean TB preparation time/case for (B) breast, (C) GI, (D) ear, nose, and throat (ENT), and (E) hematopathology across users. The standard curve shows a significant decrease in preparation time with the launch of phase 2 and an additional decrease with phase 4 for breast and a significant decrease between phase 1 and phase 4 for ENT. A marginal but not significant decrease was observed for GI. No significant changes were observed for hematopathology. The y-axis represents time (minutes [min]) taken for the nurse navigator to prepare for the TB. The x-axis represents the weeks when TBs were prepared. Blue dots represent the average preparation time in the corresponding week. Vertical lines delineate the week of the launch of the NTB application, after initial and stable integration, as indicated. Though the standard curve does not represent the best fit for the present data, it is included to aid in data interpretation. EMR, electronic medical record.
met the assumption of normality (examined by the Shapiro-Wilk test), and the Mann-Whitney (nonparametric) U test (Data Supplement) was performed otherwise; when the normality assumption was met, the Levene test was chosen to check the homogeneity of variance of the comparison groups. If the assumption of homogeneity was not held, we conducted a t test with unequal variance, applying the Welch df modification; a P value of < .05 was considered statistically significant (P values and statistical tests presented in the Data Supplement). Average preparation time per case was calculated for each week as the total preparation time divided by the number of patient cases discussed at TB; typically, all cases prepared in a given week were discussed the following week. Interquartile range (IQR) and standard deviation (SD) were calculated for the following: pre-NTB (phase 1); post-NTB (phases 2-4); manual (phase 2); post-integration (phases 3 and 4); and integration stable (phase 4).

RESULTS
Breast Cancer TB
Time-tracking data for breast cancer TBs were collected between February 19, 2018, and June 28, 2019. Fifty-nine breast TBs (n = 413 patient cases) were evaluated (Table 1). Users spent 421 hours preparing for TBs (25% nurse navigators [NNs], 44% pathology residents [PRs], 13% geneticists, and 18% radiologists [RDs]; Data Supplement). A 28% reduction in average preparation time per case was observed for all users, with a 76% decrease in SD between phases 1 and 4 (mean, 65 + 46.7 minutes; SD, 33.58 ± 8.06 minutes; P = .036; Table 1; Fig 1B). The timesaving improvements were sustained and became more evident over time.

The NN average preparation time decreased by 69%, with a 90% decrease in SD between phases 1 and 4 (mean, 33.6 + 10.3 minutes; SD, 22.68 ± 2.23 minutes; P = .005; Table 2; Fig 2A). On average, PR preparation time decreased by 34%, with a 62% decrease in SD between phases 1 and 4 (mean, 29.9 + 19.7 minutes; SD, 12.12 ± 4.61 minutes; P = .002; Table 2; Fig 2B). The proportion of preparation time contributed by other users, though sufficient for a comparative analysis, was minor (Table 2; Fig 2C).

GI Cancer TB
Sixty-one GI TBs (n = 565 patient cases) were evaluated (Table 1). Users spent 380 hours preparing for TBs (30% NN, 28% PR, and 36% RD; Data Supplement). A 23% reduction in average preparation time per case was observed for all users, with a 48% decrease in SD between phases 1 and 4 (mean, 42.6 ± 32.7 minutes; SD, 23.32 ± 12.2 minutes; P = .041; Table 1; Fig 1C).

The NN average preparation time decreased by 34%, with a 78% decrease in SD between phases 1 and 4 (mean, 14.6 ± 9.7 minutes; SD, 10.27 ± 2.25 minutes; P = .061; Data Supplement). On average, PR preparation time decreased by 16%, with a 65% decrease in SD between phases 1 and 4 (mean, 11 ± 9.2 minutes; SD, 15.21 ± 5.26 minutes; P = .42; Data Supplement). The proportion of preparation time contributed by other users, though sufficient for a comparative analysis, was minor (Table 1; Data Supplement).

ENT TB
Phase 2 was not implemented for the ENT TB; the stepped-wedge study design began with the partially integrated version of NTB. Therefore, phases 1, 3, and 4 were analyzed for this TB across all users, excluding Ns, who were only assigned to this TB in phase 3. This permitted the analysis of phases 3 and 4 for this group. Thirty-six ENT TBs (n = 408 patient cases) were evaluated (Table 1). Users spent 293 hours of preparation time (13% NN, 39% PR, 43% RD, and 5% others; Data Supplement). A 33% reduction in the average preparation time per case and a 73% decrease in SD between phases 1 and 4 (mean, 52.4 ± 35 minutes; SD, 21.58 ± 5.86 minutes; P = .009; Table 1; Fig 1D) were observed for all users. On average, PR preparation time decreased by 25%, with a 33% decrease in SD between phases 1 and 4 (mean, 20.4 ± 15.2 minutes; SD, 9.44 ± 6.37 minutes; P = .05; Table 3; Fig 3B). On average, RD preparation time decreased by 59%, with a 71% decrease in SD between phases 1 and 4 (mean, 29.8 ± 12.3 minutes; SD, 16.42 ± 4.68 minutes; P = .003; Table 3; Fig 3C).

Hematopathology Cancer TB
The hematopathology TB did not have an assigned NN in phase 1. Seventy-one hematopathology TBs (n = 480 patient cases) were evaluated (Table 1). Users spent 473 hours preparing for TBs (16% NN, 72% PR, 8% fellows, and 3% others [office staff, attending physicians, and RD]; Data Supplement). No significant changes were observed in average preparation time per case for all users or individual user groups between phases 1 and 4 (mean, 52.1 ± 51.3 minutes; SD, 21.65 ± 45.39 minutes; Table 1). Though some time-saving improvements were observed for NNs (13% reduction) between phases 2 and 4 (mean, 12.5 ± 10.9 minutes; SD, 7.43 ± 13.04 minutes) and for PRs (33% reduction) between phases 1 and 4 (mean, 50.3 ± 33.6 minutes; SD, 21.84 ± 30.33 minutes), these reductions were not significant and were associated with an increase in variance (Data Supplement).

DISCUSSION
TBs have been widely implemented as the gold standard for cancer care decision-making, yet there is little consensus in the literature about their effectiveness.1,2 TB case discussions are mandatory in some countries (eg, United Kingdom), and strain has been placed on health care systems because of the rising numbers of patients with cancer and the increased case complexity.18 However, the benefits of
### TABLE 1. Breast, GI, ENT, and Hematopathology TB Preparation Times

| Variable by Tumor Type | Phase 1 | Phase 2-4 | Phase 2 | Phases 3 and 4 | Phase 4 |
|------------------------|---------|-----------|---------|---------------|---------|
| Breast                 |         |           |         |               |         |
| No. of meetings        | 10      | 49        | 16      | 33            | 11      |
| No. of patient cases   | 60      | 353       | 93      | 260           | 120     |
| Total time, minutes    | 3,902   | 21,343    | 7,133   | 14,210        | 5,601   |
| Time/case, minutes     |         |           |         |               |         |
| Mean (SD)              | 65 (33.58) | 60.5 (19.59) | 76.7 (18.73) | 54.7 (18.06) | 46.7 (8.06) |
| Median (IQR)           | 68.5 (71.74) | 59.6 (23.13) | 76.4 (24.21) | 56.8 (15.78) | 49.4 (13.56) |
| Min                    | 23      | 37        | 38      | 37            | 37      |
| Q1                     | 27      | 51        | 63      | 46            | 40      |
| Q3                     | 98      | 74        | 87      | 62            | 53      |
| Max                    | 115     | 115       | 111     | 115           | 61      |
| ENT                    |         |           |         |               |         |
| No. of meetings        | 11      | NA        | NA      | NA            | 12      |
| No. of patient cases   | 115     | NA        | NA      | NA            | 130     |
| Total time, minutes    | 6,028   | NA        | NA      | NA            | 4,556   |
| Time/case, minutes     |         |           |         |               |         |
| Mean (SD)              | 52.4 (21.58) | 39.4 (14.45) | 39.4 (14.45) | 35 (5.86) |         |
| Median (IQR)           | 58.5 (24.88) | 36.4 (9.58) | 36.4 (9.58) | 35.9 (9.72) |         |
| Min                    | 6       | 26        | 26      | 26            | 26      |
| Q1                     | 43      | 33        | 33      | 29            |         |
| Q3                     | 68      | 42        | 42      | 39            |         |
| Max                    | 81      | 99        | 99      | 44            |         |
| GI                     |         |           |         |               |         |
| No. of meetings        | 12      | 49        | 12      | 37            | 12      |
| No. of patient cases   | 98      | 467       | 105     | 362           | 136     |
| Total time, minutes    | 4,176   | 18,687    | 4,690   | 13,996        | 4,452   |
| Time/case, minutes     |         |           |         |               |         |
| Mean (SD)              | 42.6 (23.32) | 40 (26.2)  | 44.7 (21.25) | 387 (27.88) | 32.7 (12.2) |
| Median (IQR)           | 50.5 (31.26) | 38.9 (15.21) | 39.2 (12.82) | 38.9 (15.69) | 34.3 (17.65) |
| Min                    | 13      | 0.7       | 0.7     | 18            | 18      |
| Q1                     | 26      | 32        | 33      | 31            | 21      |
| Q3                     | 57      | 47        | 45      | 47            | 39      |
| Max                    | 89      | 195       | 79      | 195           | 59      |
| Hematopathology        |         |           |         |               |         |
| No. of meetings        | 12      | 59        | 24      | 35            | 9       |
| No. of patient cases   | 98      | 382       | 155     | 227           | 75      |
| Total time, minutes    | 5,103   | 23,264    | 9,406   | 13,858        | 3,848   |
| Time/case, minutes     |         |           |         |               |         |
| Mean (SD)              | 52.1 (21.65) | 60.9 (29)  | 60.7 (31.11) | 61.1 (27.88) | 51.3 (45.39) |
| Median (IQR)           | 47.8 (29.35) | 61.4 (26.89) | 56.6 (34.23) | 63.4 (24.89) | 44.4 (39.05) |
| Min                    | 17      | 17        | 17      | 24            | 24      |
| Q1                     | 39      | 49        | 41      | 51            | 27      |
| Q3                     | 68      | 75        | 75      | 75            | 66      |
| Max                    | 79      | 174       | 136     | 174           | 174     |

**NOTE.** Empty data fields indicate variables that were not collected. Summary of median (IQR) and mean (SD) across all users for TB preparation time (minutes) per patient case for pre–NTB tumor board and post–NTB tumor board implementation (overall, manual, integrated, and stable versions).

Abbreviations: ENT, ear, nose, and throat; IQR, interquartile range; min, minimum value; max, maximum value; NA, not applicable; NTB, NAVIFY Tumor Board; Q1, middle value in first half; Q3, middle value in second half; SD, standard deviation; TB, tumor board.
| Variable by User | Phase 1 | Phase 2-4 | Phase 2 | Phases 3 and 4 | Phase 4 |
|------------------|---------|-----------|---------|----------------|--------|
| **Geneticist**   |         |           |         |                |        |
| No. of meetings  | 5       | 43        | 15      | 28             | 11     |
| No. of patient cases | 30   | 327       | 89      | 238            | 120    |
| Total time, minutes | 223  | 2,997     | 945     | 2,051          | 969    |
| Time/case, minutes |       |           |         |                |        |
| Mean (SD)        | 7.4 (1.56) | 9.2 (2.46) | 10.6 (2.78) | 8.6 (2.07) | 8.1 (2.43) |
| Median (IQR)     | 7.7 (3.38) | 9.5 (2.47) | 9.5 (2.43) | 9.2 (2.59) | 8.3 (3.26) |
| Min              | 5       | 4         | 7       | 4              | 4      |
| Q1               | 5       | 8         | 9       | 8              | 6      |
| Q3               | 8       | 11        | 11      | 10             | 9      |
| Max              | 9       | 16        | 16      | 13             | 13     |
| **Nurse navigator** |       |           |         |                |        |
| No. of meetings  | 9       | 49        | 16      | 33             | 11     |
| No. of patient cases | 55   | 353       | 93      | 260            | 120    |
| Total time, minutes | 1,849 | 4,442     | 1,450   | 2,992          | 1,234  |
| Time/case, minutes |       |           |         |                |        |
| Mean (SD)        | 33.6 (22.68) | 12.6 (5.09) | 15.6 (6) | 11.5 (4.12) | 10.3 (2.23) |
| Median (IQR)     | 29.2 (36.85) | 12.5 (6.33) | 14.9 (6.83) | 11.7 (6.11) | 10.9 (3.19) |
| Min              | 8       | 4         | 8       | 4              | 7      |
| Q1               | 15      | 10        | 11      | 9              | 9      |
| Q3               | 52      | 16        | 18      | 15             | 12     |
| Max              | 70      | 29        | 29      | 23             | 13     |
| **Radiologist**  |         |           |         |                |        |
| No. of meetings  | 3       | 49        | 16      | 33             | 11     |
| No. of patient cases | 14   | 353       | 93      | 260            | 120    |
| Total time, minutes | 188  | 4,378     | 1,340   | 3,038          | 1,034  |
| Time/case, minutes |       |           |         |                |        |
| Mean (SD)        | 13.4 (9.58) | 12.4 (6.32) | 14.4 (5.67) | 11.7 (6.63) | 8.6 (3.56) |
| Median (IQR)     | 8.2 (1.47) | 11.5 (6.75) | 15.1 (6.67) | 11.2 (7.5) | 8.9 (5.91) |
| Min              | 7       | 3         | 3       | 4              | 4      |
| Q1               | 7       | 9         | 10      | 8              | 5      |
| Q3               | 8       | 16        | 17      | 15             | 11     |
| Max              | 24      | 30        | 24      | 30             | 15     |
| **Pathology resident** |       |           |         |                |        |
| No. of meetings  | 9       | 48        | 15      | 33             | 11     |
| No. of patient cases | 55   | 349       | 89      | 260            | 120    |
| Total time, minutes | 1,642 | 9,522     | 3,397   | 6,124          | 2,364  |
| Time/case, minutes |       |           |         |                |        |
| Mean (SD)        | 29.9 (12.12) | 27.3 (13.17) | 38.2 (12.65) | 23.6 (12.28) | 19.7 (4.61) |
| Median (IQR)     | 36 (19.29) | 25.6 (15.21) | 35.2 (17.58) | 22.9 (9.4) | 20 (5.95) |
| Min              | 8       | 14        | 23      | 14             | 14     |
| Q1               | 26      | 20        | 26      | 19             | 17     |
| Q3               | 45      | 35        | 44      | 28             | 22     |
| Max              | 45      | 69        | 66      | 69             | 28     |

**NOTE.** Summary of median (IQR) and mean (SD) of geneticist, nurse navigator, radiologist, and pathology resident TB preparation time (minutes) per patient case for pre-NTB and post-NTB implementation (overall, manual, integrated, and stable versions).

Abbreviations: IQR, interquartile range; min, minimum value; max, maximum value; NTB, NAVIFY Tumor Board; Q1, middle value in first half; Q3, middle value in second half; SD, standard deviation; TB, tumor board.
FIG 2. Weekly mean breast tumor board (TB) preparation time for (A) nurse navigator, (B) pathology resident, and (C) radiology. The standard curve shows a significant decrease in preparation time (continued on following page).
TBs are apparent when evaluating complex cases, commonly resulting in changes to treatment plans and improved outcomes. As the volume and complexity of data increase, there is a need for intelligent systems that can better integrate, analyze, and interpret clinical data to enable better clinical decision-making.

The use of EMRs, laboratory information systems, or picture archiving and communication systems (PACS) to archive medical data has become critical for health care systems to establish efficient, high-quality documentation. Their implementation ensures standardization of processes and reduction in errors, and it positively affects patient treatment and privacy. However, many of these systems are restricted in functionality and often support single applications; systems that support the complex workflows of clinical practice—at both organizational and technical levels—are still required. The lack of interoperability and heterogeneity of different HIT systems have led to challenges for intra- and interinstitutional conferencing at TBs.

The discussion time for a TB case has been recently shown to be 5.5-6.5 minutes, necessitating better tools to collect, aggregate, and visualize data. To support this need, bolt-on EMR modules and/or list creation within a PACS have enabled extended functionality, although they may exhibit usability problems. To fill this gap, several startups that support the technologic needs of TBs have emerged, but, to date, most are focused on data capture rather than on treatment decisions. These shortcomings could be overcome by a cloud-based solution, like NTB, that provides an end-to-end, collaborative platform for the documentation and longitudinal presentation of patient data.

Our study showed that NTB resulted in significant and consistent reductions in overall preparation time (30%) across 3 different TBs. In the breast TB, an American College of Surgeons–accredited TB, the time and labor required to ensure complete case discussions is extensive. Use of NTB significantly reduced case preparation time and standardized the preparation process (Table 2; Figs 2A and 2B). The greatest impact was seen among NNs (69% decrease in average preparation time; 90% decrease in SD; \( P = .005 \)), likely because the NN was a single user throughout the study, compared with residents who rotated every 8 weeks. In the GI TB, though the trend reflected a decrease in case preparation time in pre-NTB (phase 1) compared with post-NTB (phases 2-4) times, and in the integrated (phases 3 and 4) compared with the manual (phase 2) version, this difference was not significant (Data Supplement). This is likely caused by a focus on radiology and variability of cancer types in the GI TB (upper GI, lower GI, and hepatopancreatobiliary). Interestingly, it was noted that existing clinical practice pre-NTB did not require RDs to prepare for TBs outside of normal image reporting, as images were directly accessed from the PACS during the conference. Thus, the introduction of NTB for this user group involved additional work, likely explaining the marginal increases in preparation time. In the ENT TB, the overall average preparation decreased significantly (33% reduction in time/case), especially after the introduction of the stable-integrated NTB (phase 4; Table 1; Fig 1D). These time savings were the greatest among PRs and RDs. Before the introduction of NTB, the ENT TB did not have an assigned dedicated NN. Therefore, the benefits observed may be due to a combination of factors, new personnel, and standardized preparation processes through NTB.

For transparency, the results of the hematopathology TB demonstrated inconsistent effects, likely because it was the cocreation site and the initial adopter of NTB. Interestingly, unlike the other 3 TBs, the hematopathology TB experienced significant variability in phase 4. Anecdotally, this coincided with work for NTB version 2 and testing of radiology integration (Fig 1E; Data Supplement). Of note, however, was the significant improvement observed for NN preparation time between manual (phase 2) and integrated (phases 3 and 4; 13% reduction in time) time points, suggesting that EMR integration greatly affected preparation time.

An additional point of interest was the reduction in process variance, demonstrated by reduced SD and IQR for preparation time across all TBs (Table 1; Figs 1B-1E). These data substantiate previous findings for the NTB pilot, in which a decrease in the SD of clinicians’ TB preparation time also was shown. Overall, an average decrease in SD of 46% was observed (range, 44%-50%), with the largest decrease observed among oncologists (50%) and the lowest observed among RDs (44%). In comparison, these results showed larger decreases in SD across the 3 TBs using NTB routinely (Data Supplement). The decrease in SD ranged from 48% in the GI TB to 76% in the breast TB (Data Supplement). Here, PRs showed decreases of 33%-62%, comparable to the 45% reduction seen among pathologists in Krupinski et al. Meanwhile, a decrease of 71% for RDs was observed for the ENT TB, which is higher than the 44% seen among RDs in the report by Krupinski et al. In our study, the largest decreases in SD were observed for NNs in the GI (78%) and breast (90%) TBs. TB NNs were not included in the study by Krupinski et al, likely because dedicated TB NNs are a novel concept recently pioneered at our institution.

**FIG 2.** (Continued). With the launch of phase 2 and an additional decrease with phase 4 for all three groups. The y-axis represents time (minutes [min]) taken to prepare for the TB. The x-axis represents the weeks when TBs were prepared. Blue dots represent the average preparation time in the corresponding week. Vertical lines delineate the week of the launch of the NAVIFY Tumor Board (NTB) application, after initial and stable integration as indicated. Though the standard curve does not represent the best fit for the present data, it is included to aid in data interpretation. EMR, electronic medical record.
These results suggest that, in addition to saving time, using NTB resulted in less variability in preparation time, which can facilitate resource planning. This improvement has important ramifications for decreasing administrative burdens of meeting preparation, protecting against EMR burnout, and supporting accurate reporting for accreditation purposes. The improvements were sustained and became more significant over time (6 months from first implementation; Figs 1B-1D) and when relatively fixed users were assigned for TB preparation (Figs 2A-2C). The importance of system integration as opposed to standalone solutions was evident.

In this study, the impact of NTB on individual users was variable, with the largest impact observed among NNs (Figs 2A and 3A). This likely is due to unburdening the NN from tasks associated with data aggregation from different systems. The impact was magnified more because only 1 NN was involved in all TBs, resulting in a steeper learning curve.

### TABLE 3. ENT TB Preparation Times

| Variable by User | Phase 1 | Phases 2-4 | Phases 3 and 4 | Phase 4 |
|------------------|---------|------------|---------------|---------|
| **Nurse navigator** |         |            |               |         |
| No. of meetings  | 24      | 24         | 12            |         |
| No. of patient cases | 278     | 278        | 130           |         |
| Total time, minutes | 2,281   | 2,281      | 984           |         |
| Time/case, minutes |         |            |               |         |
| Mean (SD)        | 8.2 (3.32) | 8.2 (3.32) | 7.6 (1.55)    |         |
| Median (IQR)     | 7.3 (3.21) | 7.3 (3.21) | 7.2 (1.66)    |         |
| Min              | 4        | 4          | 6             |         |
| Q1               | 6        | 6          | 6             |         |
| Q3               | 9        | 9          | 8             |         |
| Max              | 19       | 19         | 10            |         |
| **Radiologist**  |         |            |               |         |
| No. of meetings  | 10      | 25         | 25            | 12      |
| No. of patient cases | 101     | 293        | 293           | 130     |
| Total time, minutes | 3,012   | 4,503      | 4,503         | 1,599   |
| Time/case, minutes |         |            |               |         |
| Mean (SD)        | 29.8 (16.42) | 15.4 (8.19) | 15.4 (8.19)   | 12.3 (4.68) |
| Median (IQR)     | 33 (29.9) | 12.9 (10.34) | 12.9 (10.34) | 11 (4.7) |
| Min              | 0.5      | 7          | 7             | 7       |
| Q1               | 15       | 9          | 9             | 9       |
| Q3               | 45       | 20         | 20            | 13      |
| Max              | 50       | 45         | 45            | 23      |
| **Pathology resident** |         |            |               |         |
| No. of meetings  | 11      | 25         | 25            | 12      |
| No. of patient cases | 115     | 293        | 293           | 130     |
| Total time, minutes | 2,343   | 4,562      | 4,562         | 1,973   |
| Time/case, minutes |         |            |               |         |
| Mean (SD)        | 20.4 (9.44) | 15.6 (6.45) | 15.6 (6.45)   | 15.2 (6.37) |
| Median (IQR)     | 20.8 (9.85) | 15.3 (7.62) | 15.3 (7.62)   | 14.3 (9.34) |
| Min              | 0.5      | 7          | 7             | 7       |
| Q1               | 16       | 11         | 11            | 10      |
| Q3               | 26       | 19         | 19            | 19      |
| Max              | 35       | 34         | 34            | 28      |

NOTE. Empty data fields indicate variables that were not collected. Summary of median (IQR) and mean (SD) of nurse navigator, radiologist, and pathology resident TB preparation time (minutes) per patient case for pre-NTB and post-NTB implementation (overall, manual, integrated, and stable versions).

Abbreviations: ENT, ear, nose, and throat; IQR, interquartile range; min, minimum value; max, maximum value; NTB, NAVIFY Tumor Board; Q1, middle value in first half; Q3, middle value in second half; SD, standard deviation; TB, tumor board.
with sustained benefits. This is corroborated by the approximate 4-week-long learning curves for other roles (eg, PRs on 8-week rotations), allowing the benefit from improved efficiency in the remaining 4 weeks (Figs 2B and 3B). Institutions with dedicated staff members preparing for cases will likely benefit the most. Moreover, an integrated NTB enables equitable access to clinical data, which may support optimal decision-making and decrease individual.

**FIG 3.** Weekly mean ear, nose, and throat (ENT) tumor board (TB) preparation for (A) nurse navigator, (B) pathology resident, and (C) radiologist. The standard curve shows a significant decrease in preparation time in phase 4 compared with phase 1 for pathology resident and radiologist. The $y$-axis represents time (minutes [min]) taken to prepare for the TB. The $x$-axis represents the weeks when TBs were prepared. Blue dots represent the average preparation time in the corresponding week. Vertical lines delineate the week of the NAVIFY Tumor Board (NTB) application launch, after initial and stable integration as indicated. Note: Though the standard curve does not represent the best fit for the present data, it is included to aid in data interpretation.
bias in the selection of information. The real impact of NTB is best assessed upon implementation of a stable version following a washout phase.

The limitations of this study include the following: (1) self-recording of preparation time by participants; (2) the assumption that average case preparation time equals the total preparation time divided by the number of cases presented at the next TB, because recorded times may include preparation for cases presented at other meetings; and (3) the relatively short postintegration stable version, which does not allow assessment of longer-term benefits, though software is constantly updated, so longer-term benefits are a challenge for such studies. A last limitation is that this study only reported on preparation time but did not capture the other multiple benefits of NTB (eg, meeting quality, case discussion time, ease of planning). These factors remain to be assessed in future studies.

An additional manuscript is in preparation about assessing the impact of NTB on case discussion time during TB meetings and the learning curve for the solution. Future studies will investigate the impact of NTB on the quality of case discussions as well as applications in different geographies and contexts.

In conclusion, to our knowledge, this is the first large prospective study to demonstrate the significant impact of a digital solution for TBs. We demonstrated that NTB significantly decreased preparation time for users across multiple different TBs. This result supports the platform’s generalizability to other cancer types and institutional settings. In addition, implementation of NTB could have positive economic impacts for cancer care providers. Most importantly, compared with other behavioral interventions, the NTB impacts and improvements were continuous and sustained over time.

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PRIOR PRESENTATION
Presented in part at the ASCO Annual Meeting, Chicago, IL, May 31-June 4, 2019, and the Annual Conference of the Academy of Oncology Nurse & Patient Navigators, Nashville, TN, November 7-10, 2019.

SUPPORT
Supported in part by funding from Roche (including funding for medical writing support).

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AUTHORS’ DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST
The following represents disclosure information provided by authors of this manuscript. All relationships are considered compensated unless otherwise noted. Relationships are self-held unless noted. I = Immediate Family Member, Inst = My Institution. Relationships may not relate to the subject matter of this manuscript. For more information about ASCO’s conflict of interest policy, please refer to www.asco.org/rwc or ascopubs.org/ccsauthor-center.

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Stock and Other Ownership Interests: Pathedex
Consulting or Advisory Role: Roche, Caris Life Sciences, Physician Educational Resources
Consulting or Advisory Role: Caris Life Sciences, Roche
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No other potential conflicts of interest were reported.

ACKNOWLEDGMENT
Medical writing and editing support was provided by Tamara Zaytouni, PhD and Lyndsey Kostadinov via Medicalwriters.com, Zürich, Switzerland.
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