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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 hematopathology.

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.

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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 years[2] 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 intensive[6] 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.[6-9]

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

ASSOCIATED CONTENT

Data Supplement

Author affiliations and support information (if applicable) appear at the end of this article.

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CONTEXT

Key Objective

Multidisciplinary tumor boards (TBs) are widely accepted in cancer care but take clinicians a large amount of time; a digital TB solution was developed to support TB preparation, and we evaluated its impact in multiple types of TBs.

Knowledge Generated

The use of the digital TB solution increased the efficiency of case preparation for TBs across multiple users and different TBs and standardized the process.

Relevance

The introduction of the digital solution could support cancer care by standardizing workflows, reducing staff workload, and improving timely discussion of treatment decisions in a multidisciplinary setting, which consequently could lead to improved patient care.

and demonstrated how digital solutions could improve efficiency.[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.[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.[6] The pilot version of NTB evaluated in Spain reduced TB preparation time among oncologists, pathologists, and radiologists.[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):

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

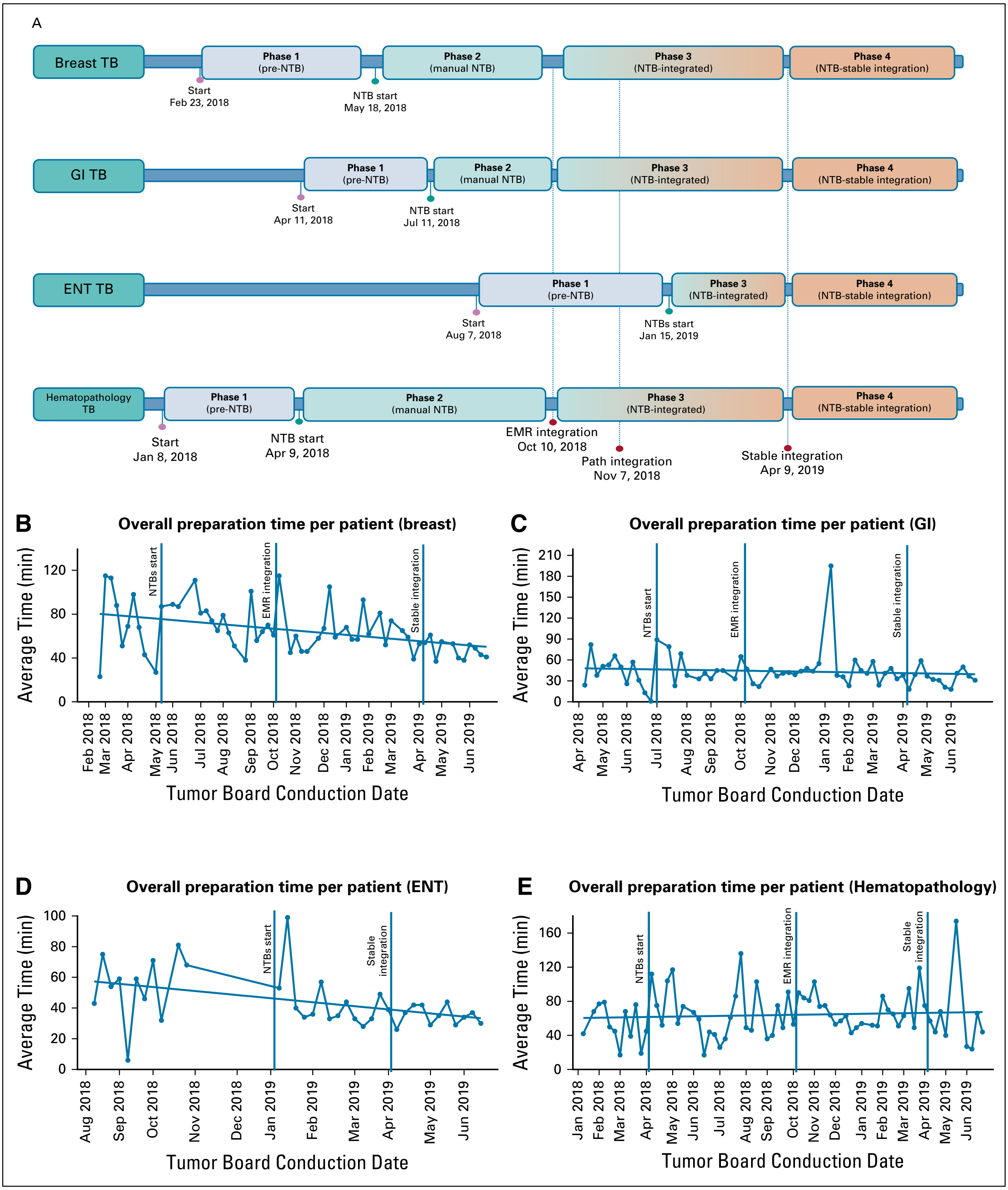

FIG 1. (A) Study design showing detailed timeline of the phased rollout of NAVIFY Tumor Board (NTB) for all tumor boards (TBs). Weekly mean TB preparation time/case for (B) breast, (C) GI, (D) ear, nose, and throat (ENT), and (E) hematopathology across users. The standard curve shows a significant decrease 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 Welsh *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 *v* 46.7 minutes; SD, 33.58 *v* 8.06 minutes; *P* = .036; Table 1; Fig 1B). The time-saving 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 *v* 10.3 minutes; SD, 22.68 *v* 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 *v* 19.7 minutes; SD, 12.12 *v* 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 *v* 32.7 minutes; SD, 23.32 *v* 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 *v* 9.7 minutes; SD, 10.27 *v* 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 *v* 9.2 minutes; SD, 15.21 *v* 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 NNs, 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 *v* 35 minutes; SD, 21.58 *v* 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 *v* 15.2 minutes; SD, 9.44 *v* 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 *v* 12.3 minutes; SD, 16.42 *v* 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 *v* 51.3 minutes; SD, 21.65 *v* 45.39 minutes; Table 1). Though some time-saving improvements were observed for NNs (13% reduction) between phases 2 and 4 (mean, 12.5 *v* 10.9 minutes; SD, 7.43 *v* 13.04 minutes) and for PRs (33% reduction) between phases 1 and 4 (mean, 50.3 *v* 33.6 minutes; SD, 21.84 *v* 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
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.

TABLE 2. Breast TB Preparation Times

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.

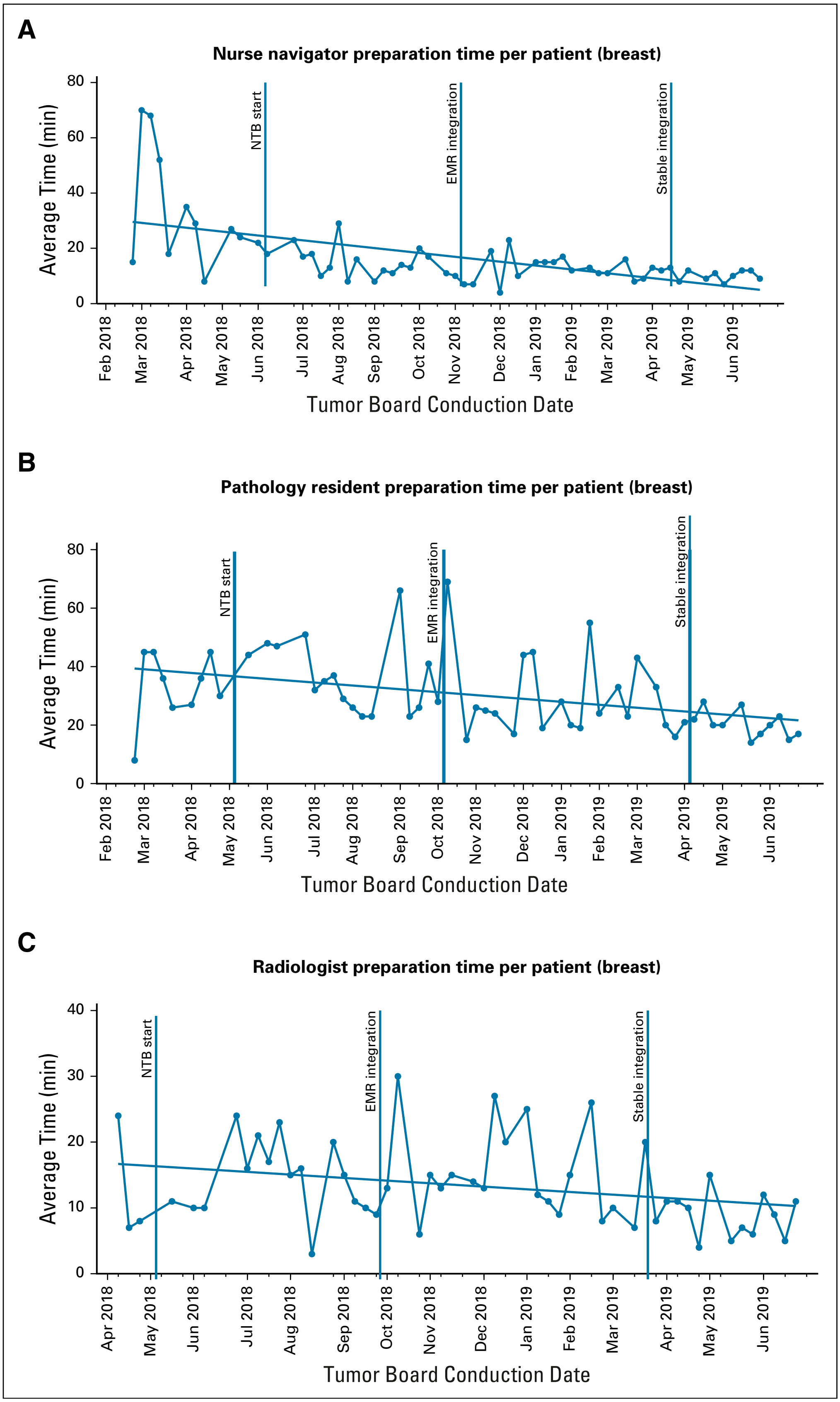

FIG 2. Weekly mean breast tumor board (TB) preparation time for (A) nurse navigator, (B) pathology resident, and (C) radiology. The standard curve shows a significant decrease in preparation time (continued on following page)

TBs are apparent when evaluating complex cases,[19] commonly resulting in changes to treatment plans and improved outcomes.[19,20] 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.[6,11,21-23] Their implementation ensures standardization of processes and reduction in errors, and it positively affects patient treatment and privacy.[6,11,21-23] However, many of these systems are restricted in functionality and often support single applications[6,24]; 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.[24]

The discussion time for a TB case has been recently shown to be 5.5-6.5 minutes,[25] 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.[14] 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.[26] 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.[6] 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%).[6] 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.[6] 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.[6] 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,[6] 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.

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.

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

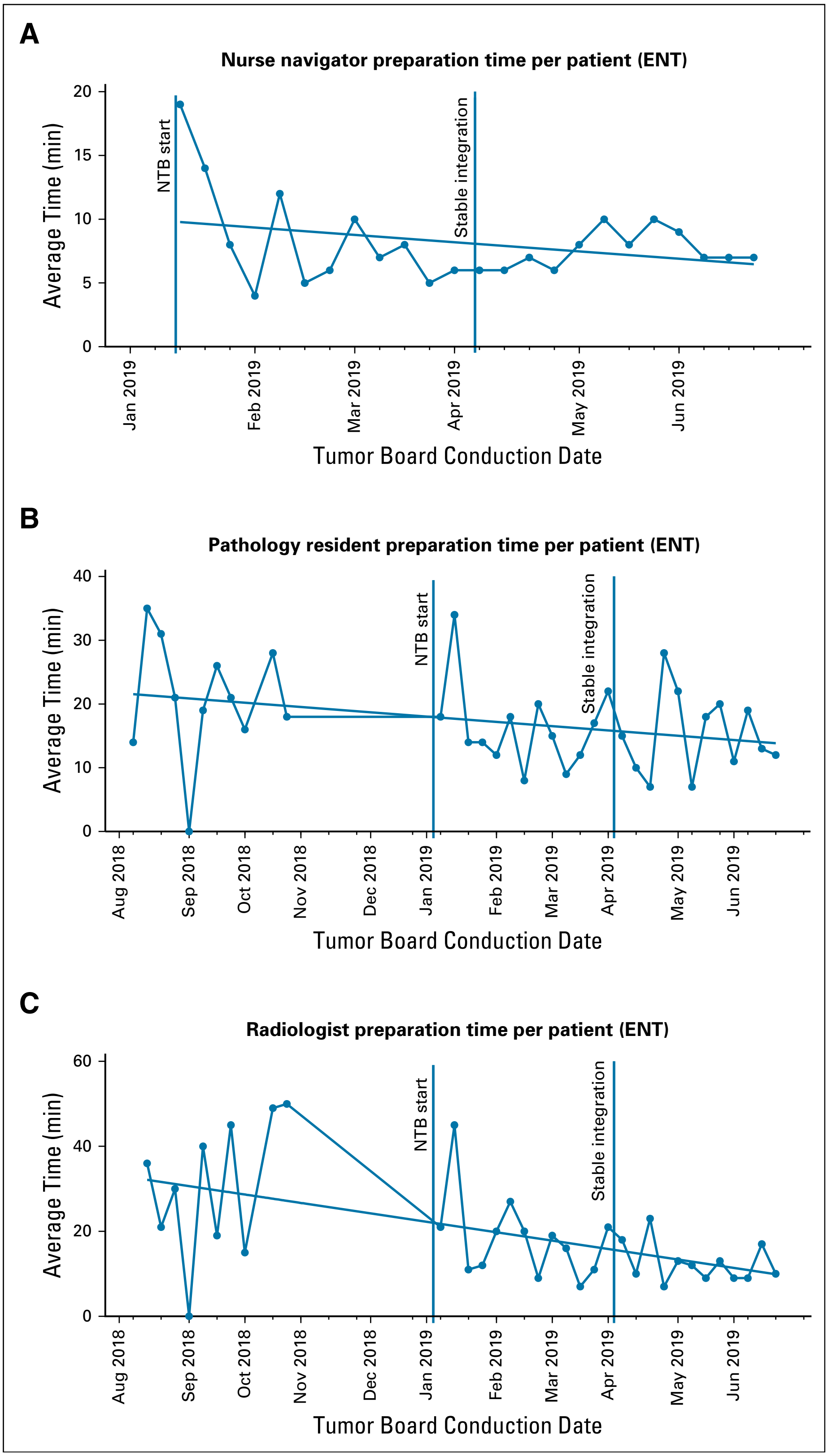

FIG 3. Weekly mean ear, nose, and throat (ENT) tumor board (TB) preparation for (A) nurse navigator, (B) pathology resident, and (C) radiologist. The standard curve shows a significant decrease in preparation time in phase 4 compared with phase 1 for pathology resident and radiologist. The *y*-axis represents 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.

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 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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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

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REFERENCES

1. Keating NL, Landrum MB, Lamont EB, et al: Tumor boards and the quality of cancer care. J Natl Cancer Inst 105:113-121, 2013
2. Berman HL: The tumor board: Is it worth saving? Mil Med 140:529-531, 1975
3. Gross GE: The role of the tumor board in a community hospital. CA Cancer J Clin 37:88-92, 1987
4. Henson DE, Frelick RW, Ford LG, et al: Results of a national survey of characteristics of hospital tumor conferences. Surg Gynecol Obstet 170:1-6, 1990
5. Soukup T, Lamb BW, Arora S, et al: Successful strategies in implementing a multidisciplinary team working in the care of patients with cancer: An overview and synthesis of the available literature. J Multidiscip Healthc 11:49-61, 2018
6. Krupinski EA, Comas M, Gallego LG, et al: A new software platform to improve multidisciplinary tumor board workflows and user satisfaction: A pilot study. J Pathol Inform 9:26, 2018
7. Knaup P, Harkener S, Ellsässer KH, et al: On the necessity of systematically planning clinical tumor documentation. Methods Inf Med 40:90-98, 2001
8. Krishnankutty B, Bellary S, Kumar NB, et al: Data management in clinical research: An overview. Indian J Pharmacol 44:168-172, 2012
9. El Saghir NS, Keating NL, Carlson RW, et al: Tumor boards: Optimizing the structure and improving efficiency of multidisciplinary management of patients with cancer worldwide. Am Soc Clin Oncol Ed Book e461-e466, 2014
10. Pender A, Garcia-Murillas I, Rana S, et al: Efficient Genotyping of KRAS mutant non-small cell lung cancer using a multiplexed droplet digital PCR approach. PLoS One 10:e0139074, 2015
11. Menachemi N, Collum TH: Benefits and drawbacks of electronic health record systems. Risk Manag Healthc Policy 4:47-55, 2011
12. Rudin RS, Jones SS, Shekelle P, et al: The value of health information technology: Filling the knowledge gap. Am J Manag Care 20:eSP1-eSP8, 2014
13. Smelcer JB, Miller-Jacobs H, Kantrovich L: Usability of electronic medical records. J Usability Stud 4:70-84, 2009
14. Adler-Milstein J, Holmgren AJ, Kralovec P, et al: Electronic health record adoption in US hospitals: The emergence of a digital "advanced use" divide. J Am Med Inform Assoc 24:1142-1148, 2017
15. Meier J, Boehm A, Kielhorn A, et al: Design and evaluation of a multimedia electronic patient record "oncoflow" with clinical workflow assistance for head and neck tumor therapy. Int J CARS 9:949-965, 2014
16. Simpson L, Mathew A: Measurement and collection of AONN+ metrics within an automated Tumor board workflow. J Oncol Navig Surviv 10, 2019
17. Hammer RD, Prime MS: A clinician's perspective on co-developing and co-implementing a digital tumor board solution. Health Informatics J doi: 10.1177/1460458219899841 [epub ahead of print on January 23, 2020]
18. Falk S: Making MDTs better. National Institute for Health Research, 2018. https://www.england.nhs.uk/south/wp-content/uploads/sites/6/2018/11/12-MDT-rforms-0618.pptx
19. Patkar V, Acosta D, Davidson T, et al: Cancer multidisciplinary team meetings: Evidence, challenges, and the role of clinical decision support technology. Int J Breast Cancer 2011:831605, 2011
20. Pillay B, Wootten AC, Crowe H, et al: The impact of multidisciplinary team meetings on patient assessment, management and outcomes in oncology settings: A systematic review of the literature. Cancer Treat Rev 42:56-72, 2016
21. Chaudhry B, Wang J, Wu S, et al: Systematic review: Impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med 144:742-752, 2006
22. Goldzweig CL, Towfigh A, Maglione M, et al: Costs and benefits of health information technology: New trends from the literature. Health Aff (Millwood) 28:w282-w293, 2009
23. Jones SS, Rudin RS, Perry T, et al: Health information technology: An updated systematic review with a focus on meaningful use. Ann Intern Med 160:48-54, 2014
24. Mangesius P, Fischer B, Schabetsberger T: An approach for software-driven and standard-based support of cross-enterprise tumor boards. Stud Health Technol Inform 212:219-224, 2015
25. Fowler D, Sheets L, Prime M, et al: The impact of a digital solution on case discussion time at tumor boards. Presented at the American Society of Clinical Oncology, Chicago, IL, May 31-June 4, 2019
26. Sweetnam C, Mocellin S, Krauthammer M, et al: Prototyping a precision oncology 3.0 rapid learning platform. BMC Bioinformatics 19:341, 2018

