A measure of case complexity for cancer multidisciplinary tumor boards: Development and early validation of the MeDiC tool

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ABSTRACT

Background and Objective. There is increasing emphasis in cancer care globally for care to be reviewed and managed by multidisciplinary teams (i.e., in tumor boards). Evidence and recommendations suggest that the complexity of each patient case needs to be considered as care is planned, however no tool currently exists for cancer teams to do so. We report the development and early validation of such a tool.

Methods. We used a mixed-methods approach involving psychometric evaluation and expert review to develop the Measure of case-Discussion Complexity (MeDiC) between May 2014 and November 2016. The study ran in 6 phases and included ethnographic interviews, observations, surveys, feasibility and reliability testing, expert consensus, and multiple expert-team reviews.

Results. *Phase-1*: case complexity factors identified through literature review and expert interviews; *Phase-2*: 51 factors subjected to iterative review and content validation by 9 cancer teams across 4 England Trusts with 9 further items identified; *Phase 3*: 60-items subjected to expert review distilled to the most relevant; *Phase 4*: item weighing and further content validation through a national UK survey. *Phases 5 and 6*: excellent inter-assessor reliability between clinical and non-clinical observers, and adequate validity on 903 video case-discussions achieved. A final set of 27 factors, measuring clinical and logistical complexities were integrated into MeDiC.

Conclusions. MeDiC is an evidence-based and expert-driven tool that gauges the complexity of cancer cases. MeDiC may be used as a clinical quality assurance and screening tool for tumor board consideration through case selection and prioritization.

INTRODUCTION

A multidisciplinary approach to cancer diagnosis and treatment appears to be the most effective means of addressing the complex needs of patients with cancer.[1-5] In fact, since 1995, the United Kingdom National Institute for Health and Care Excellence[4] proposed every newly diagnosed cancer case be discussed in a weekly multidisciplinary tumor board (MTB) meeting to improve consistency and quality of cancer care. These meetings enable a range of specialists the opportunity to review each cancer patient's case (e.g., history, imaging, comorbidities, psychosocial issues), and contribute their expert input into the formulation of treatment plans, thus optimizing care and improving patient outcomes.[1-5]

However, under pressure from increasing cancer incidence,[6-7] an aging population, financial strains on the healthcare system,[8] and specialist shortages,[9] more and more patients need to be reviewed by MTBs leaving shorter discussion times and raising quality and safety concerns.[10] Moreover, cancer provider time[11-12] and extensive preparation by radiologists and pathologists[13] is hugely expensive, inadvertently exacerbating financial pressures.[11-13] To address these concerns, both Cancer Research UK[10] and the UK National Cancer Advisory Group[5] recently highlighted prioritization of complex cancer cases as an important safety and quality improvement strategy for MTBs. This is in line with implementation of MTBs in the US, where typically the most complex (i.e. not all) patients are reviewed by a MTB to plan their care.[14] Furthermore, clinicians report case complexity as a key determinant of inconsistent MTB decision-making.[15]

Yet, what constitutes a 'complex' cancer case and factors contributing to case complexity remain unclear.[16] Clinically, case complexity might refer to specific patient characteristics (e.g., prior surgery) or cancer features that lead to prolonged MTB review that makes formulating a treatment plan challenging.[5,10,15] From a health policy perspective,[5,10] health systems are encouraged to streamline their MTB processes using validated tools to

prioritize cancer case workload, ultimately routing cancer cases efficiently through MTBs based on complexity.[5,9-10] It thus follows that some way of gauging complexity in a valid and reliable manner is necessary.

This study aims to address this need. We report development and initial validation of an evidence-based and expert-derived tool for use by cancer MTBs to safely assess complexity of a cancer patient's case and facilitate efficiency in planning treatment – the MeDiC tool (Measure of case-Discussion Complexity).

METHODS

Study design and setting

MeDiC was developed over a 30-month period (May 2014 to November 2016). It was trialled through 6 rigorous phases and a mixed-methods approach, including ethnographic interviews and observations, two rounds of national surveys, two rounds of feasibility and reliability testing on video recorded meetings, expert consensus, and multiple expert team reviews (Figure 1).

Data were collected from hospitals across England (Phases 1-3 and 5-6) and from the entire United Kingdom (Phase 4). The research was approved by corresponding local and national institutional review boards prior to data collection.

We summarize the purpose and methods for each phase of the MeDiC tool development and validation below.

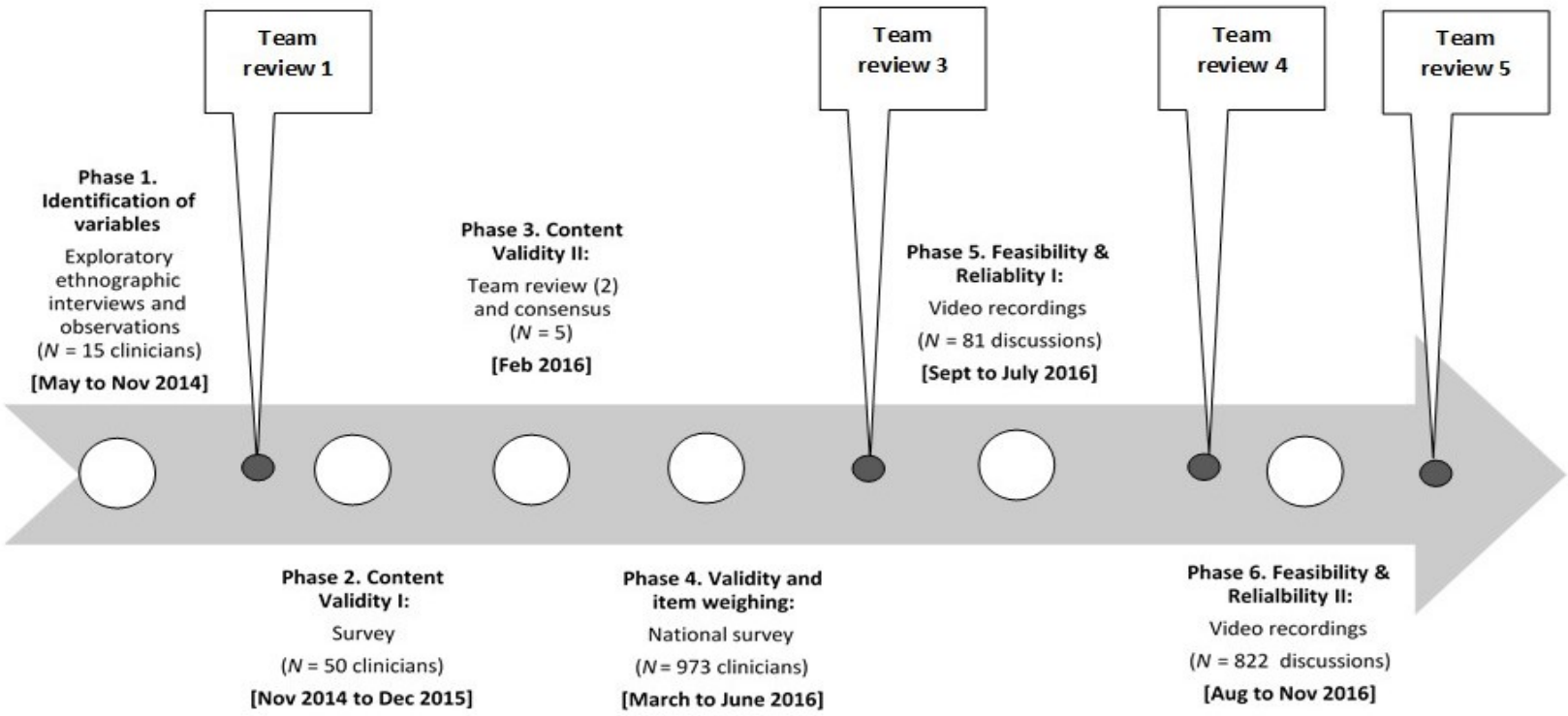

Figure 1 Development of the Measure of Case-Discussion Complexity (MeDiC) Tool for multi-disciplinary tumor board team meetings

Tool development and validation phases

Phase 1. Exploratory ethnographic interviews & observations: Complexity item identification (May-November 2014)

We conducted interviews with cancer specialists to better understand what constitutes a complex case for their MTBs. We selected participants using opportunistic sampling and asked a single open-ended question: "What factors in your opinion contribute to case-discussion complexity in cancer MTBs?" We recorded each factor put forward by the interviewees.

Phase 2. Content validation survey for case complexity items (November 2014-December 2015)

We validated Phase 1 factors with a larger sample of cancer specialists in order to determine whether they adequately represented all facets of complexity. To do so, we compiled the factors into a survey (paper and electronic version). We asked participants to rate each complexity factor on a 1-5 Likert scale (1=very simple case, rapid MTB review; 5=very complex case, in-depth MTB review). We also asked for additional factors adding to case complexity. We used the National Institute for Health Research's Clinical Research Network Portfolio to invite all hospitals with cancer MTBs in England to participate. Hospitals opting into the study distributed the survey to their MTBs through local research support teams.

Phase 3. Expert review: Preliminary content validation of complexity items (February 2016)

We held a two-hour virtual conference with expert cancer specialists (BWL & JG: attending urologic cancer surgeons; TG & KH: attending breast oncoplastic surgeons) and an expert in surgical safety and psychometrics (NS). The conference aimed to determine inclusion of factors from Phases 1 and 2 into our tool. A list of complexity factors ranked

based on their item-content validity indices (see below) was provided to the 5 experts allowing them to evaluate the candidate factors. The experts rated each factor as 'include,' 'exclude,' or 'equivocal.' Scoring was done via consensus:[16-17] all 4 cancer specialists had to agree for an item to be retained.[19-20]

Phase 4. National survey: Item weighing and national content validation (March-June 2016)

In collaboration with Cancer Research UK (one of the largest cancer support charitable foundations, which funds research, service provision, and workforce development),[10] we conducted a national survey in order to determine each individual factor's weight in terms of how much each contributes to case-complexity; and to further establish content validity of the complexity factors that emerged from Phase 3 expert consensus.

Phases 5 and 6. Video recordings of MTBs: feasibility, reliability, and validity testing (September 2015-November 2016)

We first assessed the feasibility of scoring the MeDiC tool and reliability between assessors on video-recorded MTBs. We video recorded 12 weeks of breast, colorectal, and gynecological cancer MTBs, and used the first two boards from each cancer team, respectively, for this phase. We then refined MeDiC by clarifying the wording and scoring anchors (Phase 5). We further assessed the feasibility of scoring the MeDiC items and reliability between assessors on the remaining 30 video-recorded MTBs (Phase 6).

All cancer cases reviewed at these MTBs were scored by a clinical research fellow (AM) and a research psychologist (TS) with over 5 years of expertise assessing cancer MTBs. This determined feasibility of scoring the individual items for each patient, and the reliability between the two assessors. After an initial training session (to calibrate the assessors), MeDiC

factors were separately scored using a checklist principle by each assessor and annotated to provide justification for each assigned score.

We categorized factors to be included into MeDiC into three domains for scoring. For *clinical complexity*, factor weights (as determined by the mean respondent ratings from Phase 4) were added when calculating the overall clinical complexity score. For *logistical problems*, number of occurrences within each patient review was counted, the sum of which constitutes logistical complexity score. We calculated the *overall complexity score* for each patient case by adding up clinical and logistical scores. The scores, as well as the feasibility and usability of the tool were discussed by the assessors over two in-depth data review sessions.

Data Analyses

Our overarching hypothesis was that more complex cancer cases, as scored by MeDiC, would take objectively longer time for the MTB to review and reach a treatment recommendation. We briefly describe our core endpoint analyses (validity, review length, reliability, and complexity level scoring) with full details available in Supplemental File 1.

Validity analyses

We measured content validity of complexity factors included into MeDiC using a widely-used measure, the item-content validity index (I-CVI).[19-20] This index takes both the expert rating and number of respondents into consideration. We used I-CVI ranges to guide our selection of complexity factors for retention, revision, or deletion in different phases. We further validated MeDiC using correlations between individual factors and the time spent reviewing a case at the MTB, defined as length of time (minutes:seconds) between start and end of each patient's case review. We also used the *overall complexity score* (i.e., item-total correlation). We reported partial correlations controlling for tumor type as continuous

variables, and point-biserial correlations for associations between continuous and dichotomous factors.

Reliability analyses

We assessed reliability between the two MeDiC assessors (AM and TS) using interclass correlation coefficients (ICC) for continuous variables, and Kappa for categorical items, with generally accepted reliability coefficients of 0.70 and above.[21] Cronbach's Alpha was calculated to assess for internal consistency. We also applied Cronbach's Alpha coefficient as a psychometric criterion to determine whether a complexity factor should be removed in the process of tool development.

Complexity levels scoring

We determined complexity levels using percentiles and quartile values as cut-off points. For validation purposes, we then used Kruskal-Wallis H and Mann-Whitney U tests to analyze differences in MTB review time length across different levels of case complexity.

We used bootstrapping with stratified sampling and tumor type as a stratification variable throughout the analyses.[22] All analyses were carried out using SPSS® version 20.0 with significance set at $p<0.05$.

RESULTS

In ***Phase 1***, we conducted 15 interviews with cancer specialists from 3 hospitals in England, including surgeons (*n*=7), oncologists (*n*=2), cancer nurses (*n*=2), physicians (*n*=2), radiologists (*n*=1) and pathologists (*n*=1) across lung, breast, urology, head and neck, and colorectal cancers. These specialists identified 51 complexity factors, which were grouped into four themes: pathology, patient, treatment, and MTB factors (Supplemental Table 2).

In ***Phase 2,*** we compiled the Phase 1 factors into a survey for cancer specialists. Four National Health Service Trusts in England comprising 9 MTBs (breast, brain, lung, colorectal, gestational trophoblastic disease, head and neck, skin, urology, hem-oncology) participated. Response rate was 48% (52/108) including oncologists (*n*=17), cancer nurses (*n*=11), surgeons (*n*=8), radiologists (*n*=8), physicians (*n*=6) and pathologists (*n*=2). Nine new complexity factors were suggested by survey respondents; totaling 60 items for potential MeDiC inclusion at this point of the research (Supplemental Table 2).

In ***Phase 3***, a virtual conference with 4 surgical oncology and 1 safety/psychometrics experts was held for content validation using all 60 complexity factors – listed as MeDiC potential 'items'. Out of the initial 60 items, 39 were excluded (ICV-I<0.67), and 21 received full agreement (I-CVI=1). It was further recommended by the experts that 6 items are merged due to shared meaning (i.e., cognitive with mental health comorbidities, immunocompromised with significant physical comorbidities, and treatment toxicity and contraindications to standard treatment), and 7 are grouped under the logistical issues domain; totalling 10 items for potential MeDiC inclusion at this point of the study (Supplemental Table 2).

Phase 4 incorporated complexity items (N=10) with full agreement into a national Cancer Research UK survey[9] to determine their weight and the level of complexity each factor adds. We received 973 responses (the denominator for the survey is unknown, hence a response rate cannot be computed; the absolute N of respondents was comparable to a recent UK national cancer specialist survey, which had 1,141 respondents)[24] from surgeons, oncologists, radiologists, pathologists, physicians, and cancer nurses from 10 different cancer specialties, including, breast, urology, lung, colorectal, head and neck, skin, upper gastrointestinal, gynecology, hematology, and brain across Scotland, Northern Ireland, Wales, and England, resulting in full UK coverage. We used mean ratings for each of the 10 complexity factors (items 1 to 10 in Supplemental Table 3) as weights in scoring and

determining the overall complexity of cases in subsequent phases 5 and 6. Ten new items were proposed for inclusion by respondents (items 11 to 20 in Supplemental Table 3) and retained for further evaluation with the original items; totaling 20 items for potential MeDiC inclusion at this point of the study.

In ***Phase 5***, we conducted preliminary feasibility assessment of the MeDiC scoring and psychometric analyses on a smaller sample of 5 video-recorded MTBs including 81 patient-reviews (18 breast, 34 colorectal, 29 gynecological). We determined I-CVIs, frequencies and associations with case review length during the meetings for each patient (Supplemental Table 4), along with reliability and validity testing (Supplemental Table 5).

The feasibility testing revealed several issues. Items *poor performance status, mental health comorbidity*, and *socio-economic issues* did not apply to any cases (see Supplemental Table 4), meaning their validity was not assessable, warranting further testing on a bigger sample. Similarly, items *guidelines do not account for patients' situation, treatment failure* and *lifestyle risks*, applied to only 1case each. Nonetheless, *guidelines do not account for patients' situation* (02:46 to 05:15 (min:sec) case review duration) and *treatment failure/toxicity and contraindications* led to a nearly two-fold increase in review length by the MTBs (02:46 to 04:09 (min:sec) case review duration), suggesting a potentially good proxy for complexity (see Supplemental Table 4).

Additionally, feasibility testing revealed that some of the more basic indicators of pathology are not captured in MeDiC, yet these are needed to improve the sensitivity of the tool. Therefore 7 new items were added, i.e. whether the tumor is a confirmed malignant cancer, whether it is large and has metastasized, whether it is advanced cancer, and has an invasive component, or nodal involvement, but also whether there is a residual tumor left either because of incomplete excision or because of an incomplete biological response to treatment (see items 20 to 27 in Supplemental Table 4). Although it may be counterintuitive

to have the *malignancy* as a stand-alone indicator of complexity, we found it a necessary starting point in scoring, especially, since some MTBs also discuss benign or suspicious cases. For example, a case that is malignant but has none of the other variables will be simple or of low complexity in comparison to a case that is malignant but also advanced and potentially unresectable, or incompletely excised. Hence it is the combination of different factors that determines overall complexity.

In terms of reliability (Supplemental Table 5), all cases were double-rated by the clinical and non-clinical researchers with ICCs higher than the generally accepted 0.70.[21] The Cronbach's Alpha measuring internal consistency of MeDiC scoring was good at 0.77. Hence 27 complexity items were brought into the final study phase.

Finally, ***Phase 6*** included MeDiC scoring of these 27 items and analysis on a large sample of 30 video-recorded MTBs, which reviewed and managed 822 patients (241 breast, 185 colorectal, 396 gynecological).[23] Inter-assessor scoring reliability on a subsample of 136 cases (17% of total) was good with Kappa statistics per item showing a minimum coefficient of 0.53 and maximum of 1.00. Disagreements (n=15) were due to missing elements of the case review due to recording lapses. Cronbach's Alpha measuring internal consistency was good at 0.70.

The final list of MeDiC factors with their reliability coefficients, frequency counts, and correlation coefficients with, firstly, total complexity score and, secondly, case-review duration are shown in Table 1. We color-coded items using a 'traffic-light' system for a visual guide to how well they measure complexity: green represents good measure, amber fair, and red poor (the latter are candidates for removal). Our sensitivity analysis across tumors was broadly similar to the data presented in Table 1, with the exception of 5 discrepancies detailed in Supplemental File 6.

Table 1 Final List of Complexity Factors used in the Second and Final Phase of Feasibility and Reliability Testing

	Complexity Factor	Item weighing	Assessor Reliability	Item Reliability	Item Frequency		Correlation¶					
							Item-Total‖				Case Review Duration	
			Kappa	Cronbach's Alpha if item removed†	Count	%	*r* (unadjusted)	% variability explained	*r* (adjusted§)	% variability explained	*r*	% variability explained
Pathology												
1	Malignancy	1	1.000	0.668	433	54	0.57**	33	0.47**	22	0.27**	7
2	Invasive component	1	0.984	0.669	253	31	0.56**	31	0.46**	21	0.23**	5
3	Multiple cancers (incl. multiple primaries)	1	1.000	0.688	68	8	0.38**	14	0.32**	1	0.27**	7
4	Increased size (T3, T4)	1	0.974	0.684	80	10	0.42**	18	0.36**	13	0.16**	3
5	Nodes affected	1	1.000	0.678	103	13	0.49**	24	0.40**	16	0.27**	7
6	Mets (local or distant)	1	1.000	0.667	111	14	0.57**	33	0.51**	26	0.31**	10
7	Advanced stage, progressive	1	1.000	0.676	99	12	0.50**	25	0.42**	17	0.29**	8
8	Unusual or rare tumor type	4	.953	**0.697**	34	4	**0.25****	**6**	**0.37****	**13**	**.14****	**2**
9	Residual tumor	1	0.881	0.699	47	6	0.21**	5	0.18**	3	0.16**	3
10	Recurrence	1	1.000	0.694	39	6	0.28**	8	0.27**	7	0.26**	7
Patient factors												
11	Previous history of cancer	1	1.000	**0.697**	89	11	**0.30****	**9**	**0.33****	**11**	**0.14****	**2**
12	Previous oncological treatment	1	1.000	0.685	46	6	0.41**	17	0.46**	20	0.28**	8
13	Significant surgical history	3	1.000	0.692	83	10	0.34**	11	0.49**	21	0.17**	3
14	Significant physical comorbidity (incl. poor PS††)	3	0.983	0.696	178	22	0.33**	11	0.50**	25	0.17**	3
15	Mental health and cognitive comorbidity	4	1.000	0.700	13	2	0.15**	2	0.26**	7	0.05	0
16	Socio-economic issues	3	1.000	0.701	3	0	0.13**	2	0.14**	2	0.06	0
17	Patient choice and family opinion*	1	1.000	0.701	62	8	0.23**	5	0.21**	5	0.11**	1
18	Lifestyle risks	3	1.000	0.702	7	1	0.06	0	0.08*	1	-0.01	0
Treatment factors												
19	Diagnostic uncertainty & inconclusiveness of diagnostic tests	1	0.941	0.693	105	13	0.39**	16	0.34**	12	0.29**	8
20	Unusual anatomy/ distribution of tumor	1	1.000	0.691	37	5	.33**	11	0.33**	11	0.24**	6
21	Conflict of opinions about treatment options	4	0.905	**0.703**	46	6	**0.17****	**3**	**0.32****	**10**	**0.29****	8
22	Further tests and patient assessment needed	1	1.000	**0.708**	231	29	**0.46****	**21**	**0.27****	**7**	**0.27****	**7**
23	Treatment toxicity and contraindications	3	1.000	0.699	5	0	0.17**	3	0.21**	4	0.09*	1
24	Further input needed from other specialties	1	0.978	0.701	116	14	0.27**	7	0.26**	7	0.18**	3
25	Pathway does not account for patients specific situation	4	-	0.702	1	0	.01	0	0.03	0	0.02	0
26	Trial eligibility	1	1.000	0.701	3	0	0.10*	1	0.09*	1	0.02	0
27	**Logistical complexity** (occurrences per discussion)♯	-	-	**0.953**‡	-	**42**	**0.19****	13	-	-	**0.34****	12
Total clinical complexity (sum of items 1 to 26)		-	-	**0.911**‡	-	-	-	-	-	-	**0.55****	30
Total complexity (sum of clinical and logistical scores)		-	-	**0.879**‡	-	-	**0.98****	97	-		**0.59****	35

Note. *N*=822 discussions (15 missing cases). **Green**=good measure of complexity. Yellow = fair. **Red** = weak and could be removed. **Boldface** = values changed as a result of item weighing. Percentage values have been rounded to the nearest integer for ease of reading. *$p<0.05$. **$p<0.01$. †Cronbach's Alpha is 0.701. ‡Interclass Correlation Coefficient (ICC). §Adjusted for item weighing. ‖Clinical complexity total. ¶Point-biserial correlation coefficients for items 1-26; Partial correlation controlling for tumor type for discussion time, clinical, logistical and overall complexity. ♯*R* between Total and Logistical Complexity is 0.36** (12.6% of total variance explained). ††Performance status.

We further validated MeDiC scores against a practical and objective measure of case complexity: duration of MTB review for each case presented for a management plan to be agreed. To do this analysis, we categorized complexity levels into 4 groups using three quartile medians with bias-corrected standard errors and confidence intervals (Table 2). We then applied the overall complexity levels to individual MTBs. We found the 4 complexity levels were significantly distinct with gradual increases in mean time spent reviewing each patient ($\chi^2(3) = 309.67$, $p < .001$) – which provided further validation that MeDiC truly captures underlying case complexity. As shown in Table 2, 43% of colorectal cases fell within the top 25% of the data, i.e., within the very high complexity range. In contrast, the gynecological MTB had had the smallest frequency of high/very high complexity cases, with low to moderately complex cases most prevalent. The breast cancer team had a more balanced spread of patient complexity. Summary statistics of the entire clinical complexities across participating MTBs as assessed by MeDiC are shown in Table 3.

Table 2 Summary Statistics for the Total MeDiC Complexity Score Across Tumor Boards and Overall Dataset

Cancer team	***N***	***Mean (SD)***	***Median (IQR)***	**Minimum, Maximum**	**Logistical problems**	
					count	%
Breast	241	4 (4)	3 (4)	0, 18	84	29
Gynecological	396	3 (4)	2 (3)	0, 26	134	48
Colorectal	185	6 (4)	6 (5)	0, 19	121	23
Total	822	4 (4)	3 (5)	0, 26	339	41

Note. SD =standard deviation. *IQR* =interquartile range. % is a percentage of observed cases where logistical problems were present. MeDiC total score range is 0 to 26, with higher scores indicating higher case-complexity.

DISCUSSION

To the best of our knowledge, this study offers the first tool to assess the clinical complexity of a cancer patient managed in a tumor board setting. Through a rigorous multiphase research process, with expert input from cancer specialists, we produced the MeDiC tool with evidence of reliability and validity in its scores, feasibility in utilization, and correlation with length of time a case review takes across different tumors. Our analysis confirmed the hypothesis that the cases that obtain higher MeDiC scores take significantly longer time to discuss and make a treatment plan for within MTBs – thus validating the underlying complexity dimension that MeDiC is intended to capture.

We see numerous ways in which MeDiC can be used by MTBs. In health systems where only a select set of cancer patients are brought to a MTB for review, as is the case in the United States, MeDiC offers a standardized tool to facilitate, standardize, and report how the cases are selected for MTB review. We propose that in such systems cases could be selected based on complexity – with the cut off determined by individual MTBs. Using MeDiC in this approach would allow less complex cases to be treated according to well-defined guidelines and evidence-based protocols agreed on by the entire MDT. While being selective is often the *de facto* approach used in the United States where institutional cancer accreditation (e.g., American College of Surgeons Commission on Cancer)[28] might rely on presenting a proportion of cancer patients at a cancer conference, there is typically not a systematic distinction based on case complexity. This could lead institutions to potentially meet the measure but not consistently among those most likely to benefit (i.e., complex patients) and without documentation of doing so. These cases could instead be managed through the MTB chair, ratified by team members with quality assurance maintained through specialist review of pathology and radiology investigations, and regular audit of recommended treatment options. This would redistribute the MTB work towards cases with greater clinical need as illustrated in Figure 2.

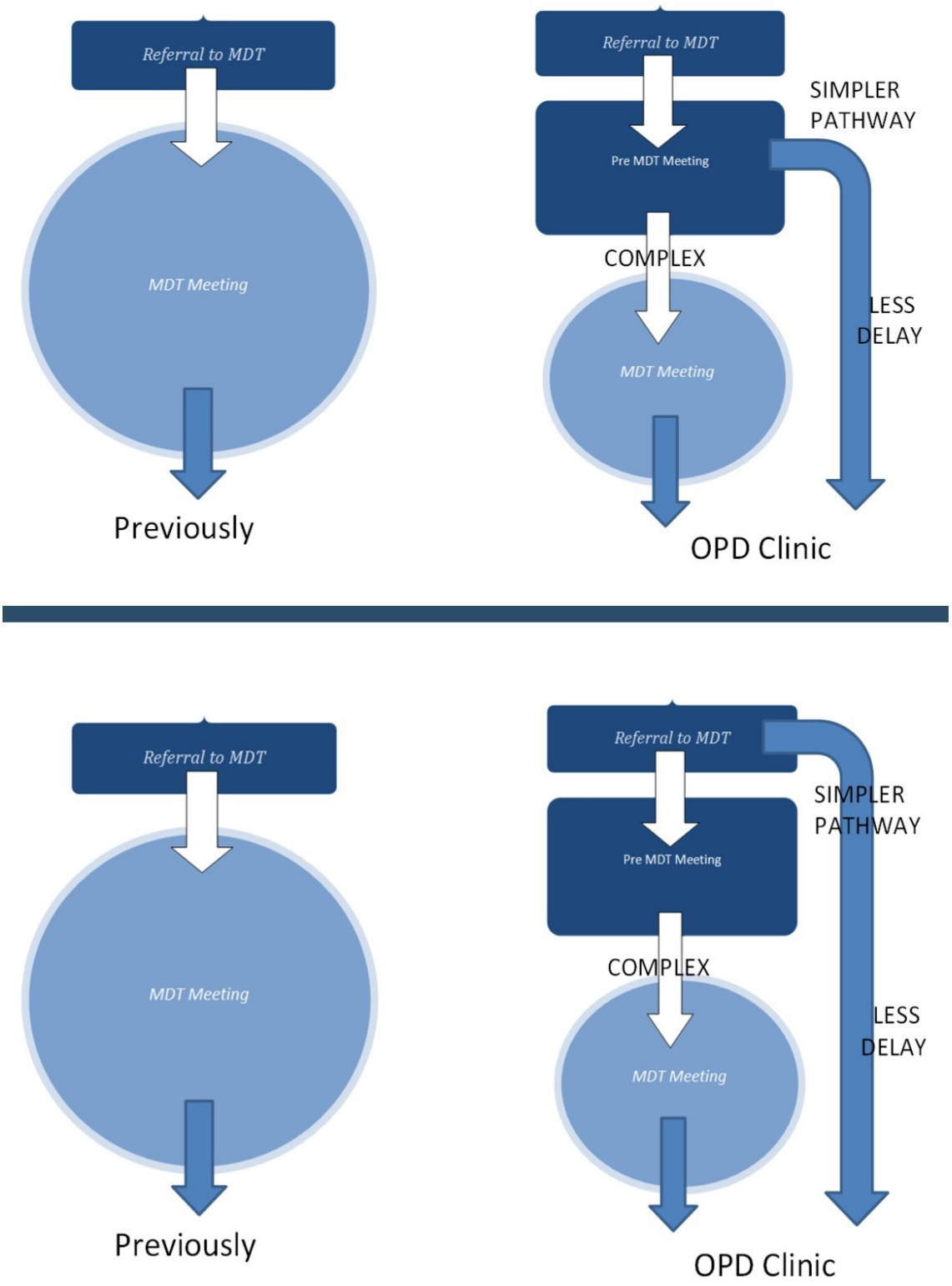

Figure 2 Example of how Measure of Discussion Complexity (MeDiC) could be used to streamline workload

Further, in health systems where MTBs are mandatory, e.g., in the UK, current policy discussions reveal concern regarding the sustainability of such uniform application of MTBs; and clinically, there is the imbalance of more complex patients being squeezed for time due to very long case-lists the MTB has to review. Indeed, prior research by our team has found that the median duration of a case review by a MTB is 2mins, which means that some patients are being 'discussed' in an even shorter timeframe.[10,25,27] Based on both our clinical and research experience, these very briefly reviewed cases would score low on MeDiC – i.e., they represent the least complex patients. In healthcare systems such at the one of the UK, MeDiC offers the opportunity to consider screening of the highest scoring (i.e., most complex) patients for full MTB review; and allowing the least complex patients to be managed according to well-defined guidelines and standard pathways and ratified at the MTB.

Lastly, in health systems where MTBs are not applied, MeDiC allows for a phased introduction of this approach, without overloading system resources: selecting patients according to how clinically and logistically complex they are, thus allowing such systems to experiment with setting up their cancer management pathways in a gradual manner – i.e., by being selective regarding which patients they bring to the MTB's attention.

Based on our finding of variation in case complexity across tumor types, one MTB implementation design is unlikely to fit all situations. MTBs based at different centers that has different case mixes will have different requirements – for example, a tertiary referral cancer center will by definition deal with the most complex cases, either regionally or nationally. The MeDiC tool allows cancer centers to (re-)design their care processes safely, with adequate governance in enabling patients to be streamlined through the MTB framework effectively. Regardless of how MeDiC is used, it is important that complex cases be reviewed at the beginning of a cancer conference, when teams are fresh, to prevent cognitive fatigue shown to impact decision-making.[25-27] Evidenced cognitive-behavioral strategies should be

implemented (e.g., a short break mid-meeting) if meetings are particularly long (>1 hour) to prevent performance detriments.[27]

This study has limitations. Firstly, MeDiC was developed and tested within the UK's fully MTB-driven cancer care system. Further testing is needed in other settings where tumor boards are not mandatory and information regarding the clinical complexity may be dispersed across systems and harder to assimilate. Secondly, MeDiC was tested in real time during MTBs. For most teams, however, the tool should be used to help with meeting preparation and streamlining. The tool could be completed to generate a score when the decision to present a patient is made with subsequent case selection or ordering of cases on the MTB's agenda (to start with the most complex patients). Thirdly, the expert review team consisted of predominantly surgeons and psychologists, hence insights from other specialists might be lacking. Nonetheless, all factors included in MeDiC were reviewed by a diverse national range of cancer specialists, thus adding credibility and validity to the tool.

Further research on MeDiC should explore how cut-off scores could be established for each tumor or MTB type – we cannot assume that these will be uniform for all. Clinically, further sensitivity analyses need to be carried out, to ensure MeDiC does not miss complex patients in any way. From a cancer policy point of view, implementation of MeDiC and study of its impact on patient selection, efficiency and costs of care will allow health systems policy makers to determine how MTB-driven care can be optimally implemented to enhance quality and efficiency in cancer care delivery.

Conclusion

MeDiC offers an evidence-based and expert user-informed tool that allows cancer teams and systems to select and/or streamline their patient caseload for optimal treatment planning and management.

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ADDITIONAL INFORMATION

Ethics Approval and Consent to Participate

Ethical approval for the study was given by the North West London Research Ethics Committee, and also locally by the R&D departments of the participating NHS Trusts (JRCO REF. 157441). Consents were obtained from the participants throughout the phases.

Availability of Data and Materials

The anonymized data set supporting the final phase of tool development is available on Zenodo, a research data repository, under the Creative Commons Attribution Non-Commercial Non-Derivative license. Researchers are free to reuse and redistribute the data set on the condition that they *attribute it*, that they *do not use it for commercial purposes*, and that they *do not alter it*. For any reuse or redistribution, researchers must make clear to others *the license terms* of this work and cite and reference the data set accordingly (for an example of referencing a data set, please, refer to reference 23). The copyright of the MeDiC tool and items rests with Soukup, Sevdalis and Green, and the final version of the tool with item description can be obtained from Soukup on request.

Authorship

In line with the guidelines by the International Committee of Medical Journal Editors, all authors for this study have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; have been involved in drafting the manuscript or revising it critically for important intellectual content; have given final approval of the version to be published; and have agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Department of Health. Manual for Cancer Services. London, Department of Health; 2004.
2. National Cancer Action Team. The characteristics of an effective multidisciplinary team (MDT). London, National Cancer Action Team; 2010.
3. Fennell ML, Das IP, Clauser S, Petrelli N, Salner A. The organization of multidisciplinary care teams: modelling internal and external influences on cancer care quality. *J Natl Cancer Inst Monogr.* 2010;40:72-80.
4. National Institute for Health and Care Excellence. Improving Outcomes Guidance (IOG). https://www.nice.org.uk/guidance/published?type=csg. Accessed February 04, 2019.
5. Independent Cancer Taskforce. Achieving world-class cancer outcomes: a strategy for England 2015-2020. Independent Cancer Taskforce; 2015. Available from: tinyurl.com/taskforce-strategy. Accessed February 21, 2015.
6. Mistry M, Parkin DM, Ahmad AS, Sasieni P. Cancer Incidence in the UK: Projections to the Year 2030. *Br J Cancer.* 2011;105:1795-803.
7. World Health Organization. World Cancer Report 2014. France, International Agency for Research on Cancer; 2014.
8. NHS England. Everyone Counts: Planning for Patients 2014/2015 to 2018/2019. London, NHS England; 2014.
9. NHS Improvement. Evidence from NHS Improvement on clinical staff shortages: A workforce analysis. London, NHS Improvement; 2016.
10. Cancer Research UK. Improving the effectiveness of multidisciplinary team meetings in cancer services. London, Cancer Research UK; 2017.
11. Fosker CJ, Dodwell D. The cost of the MDT. *Br Med J.* 2010;340:c951.

12. Taylor C, Shewbridge A, Harris J, Green JS. Benefits of multidisciplinary teamwork in the management of breast cancer. *J Breast Cancer.* 2013;5:79-85.
13. Kane B, Luz S, O'Briain DS, McDermott R. Multidisciplinary team meetings and their impact on workflow in radiology and pathology departments. *BMC Med.* 2007;5:15.
14. Prabhu Das I, Baker M, Altice C, Castro KM, Brandys B, Mitchell SA. Outcomes of multidisciplinary treatment planning in US cancer care settings. *Cancer.* 2018. 124(18):3656-3667.
15. Kidger J, Murdoch J, Donovan JL, Blazeby JM. Clinical decision-making in a multidisciplinary gynaecological cancer team: a qualitative study. *Int J Obstet Gy.* 2009;116(4):511-517.
16. Proctor BJ, Waltz TJ, Chinman MJ, Damschroder LJ, Smith JL, Mattieu MM, Proctor EK, Kirchner JE. A refined compilation of implementation strategies: results from the Expert Recommendations for Implementing Change (ERIC) project. *Impl Sci.* 2015;10:21.
17. Hsu C-C, Sandford BA. The Delphi technique: Making sense of consensus. Pract Asses Res Eval 2007; 12(10). Available from: http://pareonline.net/getvn.asp?v=12&n=10. Accessed September 01, 2014.
18. Dalkey N, Helmer O. An experimental application of the Delphi Method to the use of experts. *Manag Sci*. 1963;9:458–467.
19. Polit DF, Beck CT, Owen SV. Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Res Nurs Health.* 2007;30:459-467.
20. Polit DF, Beck CT. The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Res Nurs Health*. 2006;29:489-497.

21. Hull L, Arora S, Symons NR, Jalil R, Darzi A, Vincent C, Sevdalis N. Delphi Expert Consensus Panel. Training faculty in nontechnical skill assessment: national guidelines on program requirements. *Ann Surg.* 2013;258(2):370-375.

22. Wright DB, London K, Field AP. Using bootstrap estimation and the pug-in principle for clinical psychology data. *J Exp Psychopathol.* 2011;2(2):252-272.

23. Soukup T. Complexity of patient-discussions in cancer meetings [Data set]. Zenodo; 2017. http://doi.org/10.5281/zenodo.582279

24. Lamb BW, Sevdalis N, Taylor C, Vincent C, Green JSA. Multidisciplinary team working across different tumour types: Analysis of a national survey. Ann Onol. 2012;23:1293-1300.

25. Lamb BW, Sevdalis N, Benn J, Vincent C, Green JS. Multidisciplinary cancer team meeting structure and treatment decisions: A prospective correlational study. *Ann Surg Oncol*. 2013;20:715–722.

26. Soukup T, Lamb BW, Weigl M, Green, JSA, Sevdalis N. An Integrated Literature Review of Time-on-Task Effects With a Pragmatic Framework for Understanding and Improving Decision-Making in Multidisciplinary Oncology Team Meetings. *Front Psychol*. 2019;10:1245.

27. Soukup T, Gandamihardja T, McInerney S, Green JSA, Sevdalis N. Do multidisciplinary cancer care teams suffer decision-making fatigue? An observational, longitudinal team improvement study. *BMJ Open*. 2019;9:e027303.

28. American College of Surgeons. Commission on Cancer. Available from: https://www.facs.org/quality-programs/cancer/coc. Accessed March 25, 2019.

Table 3 Complexity Levels and Mean Case Review Time Durations Across Tumor Boards and Overall Dataset (all tumor boards)

	25th percentile	50th percentile	
Complexity **score**:	**≤1**	**2-3**	**4-6**
Complexity **level**:	**Low**	**Moderate**	**High**
Breast cancer tumor boards			
% of case reviews	**33%**	**23%**	24%
Mean review time (MM:SS)	00:52	02:06	02:38
Median review time (MM:SS)	00:36	02:03	02:28
Range review time (MM:SS)	02:21	03:59	05:13
N of case reviews	**79**	**56**	58
Gynecological cancer tumor boards			
% of case reviews	**33%**	**34%**	18%
Mean review time (MM:SS)	01:28	02:11	03:13
Median review time (MM:SS)	01:15	02:00	03:00
Range review time (MM:SS)	05:09	10:59	07:35
N of case reviews	**130**	**135**	72
Colorectal cancer tumor boards			
% of case reviews	8%	20%	**30%**
Mean review time (MM:SS)	01:01	02:09	02:34
Median review time (MM:SS)	01:11	02:07	02:20
Range review time (MM:SS)	02:09	04:44	06:04
N of case reviews	14	37	**55**
Overall dataset (all tumor boards)			
% of case reviews	**27%**	**28%**	23%
Mean review time (MM:SS)	01:13	02:10	02:50
Median review time (MM:SS)	01:06	02:00	02:27
Range review time (MM:SS)	05:09	11:02	07:47
N of case reviews	**223**	**228**	185

Note. Categories are based on quartile median values from overall dataset bootstrapped on 5000 stratified samples with tumor type as a stratification variable. Median (upper and lower bias corrected confidence intervals) for the 25th percentile was 1 (1.14-1.56), for the 50th percentile was 3 (2.99-3.46), and for the 75th percentile 6 (5.64-6.57).