Computer decision support for cancer multi-disciplinary meetings: The Royal Free experience

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Figure 1. MATE in use at Royal Free breast MDT meeting.
454x165mm (300 x 300 DPI)

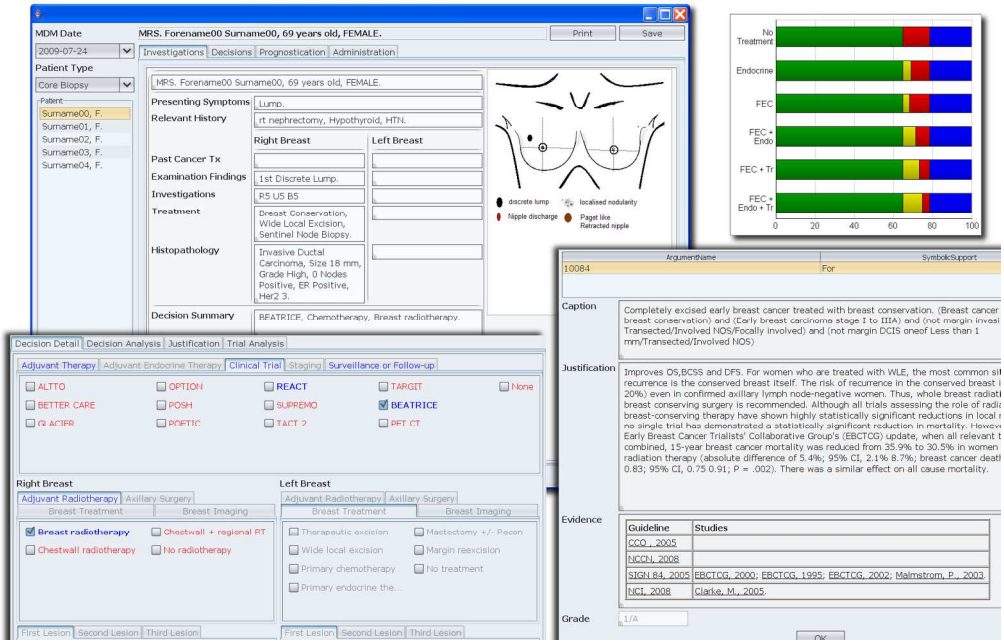

Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Computer decision support for cancer multi-disciplinary meetings: The Royal Free experience
Type- An analysis of new technique/ Quality improvement report

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Article summary

Article focus:

-How to improve the conduct of a cancer MDT and standardize decision-making in accordance with best evidence

- Development and implementation of a novel clinical decision support (CDS) platform for cancer MDT

- Pilot evaluation results

Key messages:

- An advanced CDS platform could significantly improve the conduct of cancer MDT meetings.

- Further robust evaluations are necessary.

Strengths and limitations:

- We share our valuable experience of developing an advanced decision support system and implementing in a complex clinical environment of cancer MDT which is subsequently adopted as a breast MDT meetings management tool.

-The results reported here, however encouraging, are at this point indicative of the potential benefits but not yet conclusive. They should be treated with caution until further rigorous evaluations confirm the effectiveness and generalisability of the CDS system.

Data sharing statement:

There is no additional data available.

Research checklist:

Appropriate research checklist could not be found.

Abstract:

Problem The cancer multidisciplinary team (MDT) meeting is regarded as the best platform to reduce unwarranted variation in cancer care through evidence-compliant management. However, MDT meetings are often overburdened with many different agendas, and hence struggle to achieve their full potential.

Design We have developed an interactive computer system called MATE to facilitate explicit, evidence-based decision making in MDT meetings for breast cancer care.

Setting We describe the system; share our experience of implementing MATE and report initial audit and survey results.

Key measures for improvement Compliance with evidence-based guidelines and the ability to identify patients for accrual into ongoing clinical trials.

Strategies for change The emphasis is on active user participation through audit, feedback and response, acknowledging the clinical needs and practical constraints of the MDT and fitting the system around the team's work-flow rather than the other way around.

Effects of change MATE identified 61% more patients who were eligible for recruitment into clinical trials than the MDT and its recommendations demonstrated high concordance with MDT decisions (93.2 %; N = 984). MATE is in routine use in breast MDT meetings at Royal Free hospital, London and deployment of the system in other NHS trusts is being explored.

Lessons learnt Sophisticated decision support systems can enhance the conduct of MDT meetings in a way that is acceptable to and valued by the clinical team. Further rigorous evaluations are required to examine cost-effectiveness, measure the impact on patient outcomes and test the generalisability of the system in different hospital setups and in different cancers.

Problem statement

Unwarranted practice variation across different medical domains has unfortunately become a pervasive finding in health service research and breast cancer care is no exception.[1] A recently published study reported significant differences in breast cancer survival across hospitals in the same geographical region in England.[2] The reasons for practice variation are multifactorial and standardisation of care has been attempted by the introduction of Regional Cancer Networks in England and the adoptions of the Multi Disciplinary Team (MDT) model to promote maximal adoption of evidence-based practice.

Many benefits of MDTs have been claimed, but few have been backed by strong evidence.[3] However, despite a significant lack of prospective evidence, MDTs are well accepted in clinical practice; they are regarded as a major advance in management of cancer patients and their use appears to be increasing.[4] As many health care systems have already committed to and invested in the MDT model, further reductions in unwarranted variation are likely to be best achieved by improving their conduct and standardizing their decision making processes.[5] Data collected by the UK national cancer peer review programme from over 1000 teams across six cancer types in England indicates that there is significant room for improvement in the conduct of MDT meetings. The analysis reported by Taylor et al, shows considerable variability in the performance of MDTs.[3] A recent national survey of more than 2000 members of cancer multidisciplinary teams, demonstrated agreement on the range of criteria necessary for effective MDT working.[3] A review of the literature by the authors identified many pragmatic challenges and shortcomings in the current conduct of cancer MDT meetings summarised in Table 1.[6]

Context

The Royal Free Hospital NHS Trust (RFH) serves a population of 2.6 million within the North London Cancer Network (NLCN) catchment area. The number of new patients (both benign and cancer) seen as outpatients by the breast unit in 2009-10 was 2,944.

The Breast Cancer Multidisciplinary team at RFH was established in 2005, in line with the recommendations of the NHS Cancer Plan. The MDT uses a set of NLCN-approved clinical guidelines and a standardized minimum data set.

MDT meetings (MDM) are held every week in a conventional conference format. The core members of a breast MDT include breast surgeons, radiologists, pathologists, medical and clinical oncologists, plastic surgeons and breast care nurses. A typical breast MDM discusses an average of 30 to 40 patients at various stages in their care pathways every week to decide further courses of action.

Prior to the introduction of our computer-based service into the MDT meetings, an entirely paper based record system was used to provide case summaries and to document the MDT's discussion and decisions. These records contained free (unstructured) text rather than the coded and structured data used by a modern electronic health record (EHR). The tradeoffs between structured and unstructured EHRs are well known.[7] The main drawbacks of an unstructured MDT record are that it hinders attempts to accurately measure the performance of the MDT and provision of automated data analysis processes and implementation of alerts and reminders, and decision support etc.

There are many commercially available information and communication systems such as EHR systems which can assist in the preparation, presentation and documentation of cases at the MDT meetings. However the objectives of our MDT service improvement exercise was to go beyond improvements in data management by providing active support for evidence-based decision making, improving recruitment into clinical trials and supporting prospective audit.[8]

Measures of improvement

Evidence compliant care: Adherence with clinical practice guidelines

With the increasing recognition of shortcomings in healthcare systems, there is a significant cultural and professional shift towards using evidence-based guidance. Evidence-based standards of care, such as published practice guidelines and technology assessment reports developed by authoritative organisations provide an objective

standard against which to assess MDT decisions. There is growing evidence that use of evidence-based guidelines can improve patient outcomes,[9, 10]-[11] and MDT meetings provide the best opportunity to actively promote an *appropriate* and *judicious* use of the guidelines at the point of care.

Promoting research: Identification of patients eligible for ongoing research trials

It is widely accepted that recruiting patients into clinical trials is an effective strategy for ensuring that cancer patients get the best care as well as providing important information about the efficacy of treatments. However, the literature continues to report low rates of accrual to cancer clinical trials,[12] and many organisations at national and international levels are investigating strategies for improving accrual rates. Cancer MDT meetings represent a major opportunity for identifying patients who are eligible for participation in clinical trials.[13]

Methods

In order to assess the performance of the breast MDT on the above mentioned measures we developed a computerised decision support system, **MATE** (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), that captures patient data, identifies eligible patients for clinical trials and suggests evidence-based treatment recommendations. MATE also captures MDT decisions and hence can automatically compare them with guideline recommendations.

System development

We followed a systematic, stepwise approach throughout the system development lifecycle. Requirements for MATE were identified through a systematic review of the literature and by working closely with members of the breast MDT at RFH. We adopted the CommonKADS methodology to develop a comprehensive process and knowledge model for breast cancer MDT meetings.[14] A controlled vocabulary was used to facilitate data standardisation. The evidence sources reviewed included Clinical Practice Guidelines, Systematic Reviews and Meta-analyses and reports of Randomised

Controlled trials. Along with the guideline recommendations, the eligibility criteria of ongoing clinical trials in breast cancer that were open for the recruitment at our institution were also coded into the system. PRO*forma*,[15] a decision modelling language for formalising clinical decisions and care pathways, was used for the formal evidence representation in MATE. The PRO*forma* language and application development software Tallis used in this project were originally developed at Cancer Research UK; Tallis is now being developed at Oxford University. Tallis was used to implement a range of decision support and other services[1] as determined by the requirements development process outlined above, and is used to update recommendations and other components of the PRO*forma* knowledge base when new guidance is published. The user interface of MATE is illustrated in Fig 2. The detailed description of the knowledgebase, technology and architecture is published elsewhere[2].

We used the following processes to understand and analyse the design issues and to feed back clinical experience into the MATE development lifecycle.

Evaluation phase

MATE was used to prospectively record the proceedings of breast MDT meetings between April 2008 and July 2009 to gather 1,295 cases discussed in the MDMs during this period. Appropriate ethics and R & D approvals were obtained before starting the study, and data-security measures such as encryption were put in place. MATE allows us to capture both patient data and MDT decisions in a structured form. MATE records were cross-checked with the official MDM record sheets and, in case of any discrepancies, the MATE record was corrected to reflect the official MDM record.

One of the key distinctive features of MATE compared to a traditional electronic health record is the clinical decision support (CDS) element. MATE is able to evaluate patient data and to *actively* offer guideline-based recommendations in real time which are specific for each individual patient. We used MATE to compare *the actual MDT decisions* to that of *guideline recommendations.*

[1] http://mate.cossac.org/

[2] Acosta, D. et al., 2010. Challenges in Delivering Decision Support Systems: The MATE Experience. In *Knowledge Representation for Health-Care. Data, Processes and Guidelines*. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, pp. 124-140. Available at: http://dx.doi.org/10.1007/978-3-642-11808-1_11.

The discordant cases (where MATE recommendations differed from those of MDT decisions) were further investigated by a panel who reviewed the patient's clinical notes.

MATE also automatically flags patients who meet eligibility criteria for ongoing clinical trials.

Structured feedback

The MATE development team was invited to conduct a workshop at the England Cancer Networks' Development Programme conference in March 2010, The conference was attended by key members from all cancer networks, who are instrumental in governing and improving MDT conduct in their respective cancer networks. MATE was demonstrated in the workshop and a questionnaire survey was conducted at the end of the presentation and discussion session.

Results

Evaluation phase results

A total of 1,295 breast cases were recorded on MATE between April 2008 and July 2009 (each time a patient was discussed in the MDT meeting was counted as a separate encounter). The case mix included cancers and benign pathologies. Table 2 shows the overall distribution of cases recorded on the MATE system during the study system. Metastatic, recurrent and non epithelial malignancies were excluded from the guideline concordance analysis as the guidelines and evidence-base for those subsets were not initially coded in MATE. In 239 cases of recurrent, metastatic or non-epithelial malignancies, MATE therefore provided data capture services but no decision support. The remaining 1056 cases were analysed for concordance between management recommendations made by MATE and the actual MDT decisions and the level of concordance was encouragingly high (93.2 %; N = 984). When the discordant cases were further analysed it was found that 3.2% of MDT deviant decisions were corrected by the treating clinician in the results clinic.

MATE also identified 61% more patients who were eligible for the recruitment into clinical trials than the MDT.

Structured Feedback

The MATE workshop at the Cancer Networks' Development Programme conference was attended by 54 people, of whom 48 completed the questionnaire. Most respondents (95.8%) agreed that clinical decision support has a useful role in cancer MDMs. The majority of respondents found the services provided by MATE useful for the breast MDM (93.47) and potentially for other types of cancer MDMs (92.6%).

The survey also identified important barriers to large-scale deployment of MATE. The main perceived obstacle to adoption was double data entry (50%) in situations where existing data capture systems are in place and it was suggested that MATE should be able to interface with existing data capture systems. Other barriers identified were costs and resources, clinical buy-in, scalability and the need for practical knowledge validation and maintenance mechanisms.

Strategies for change and effects

The encouraging performance of MATE in this initial phase established the confidence of the breast team at RFH, and MATE was subsequently introduced as the standard breast MDM management tool. Introducing a new technology into as complex a setting as the cancer MDM was a challenging task and our implementation strategy was guided by the experiences of others reported in the literature.[16, 17]

The principles of the implementation strategy for MATE are summarised as follows.

- *Building around the existing clinical work-flow:* In order to ensure the clinical acceptability of MATE, a key design objective was to fit the system around the existing work-flow of the breast MDM and not the other way round.
- *Anticipating clinical needs and pragmatic constraints:* As well as obvious requirements such as access to detailed patient data, a number of other useful

services were identified during the modelling phase (e.g quick access to past MDT decisions)..

- *Active involvement of users throughout audit, feedback and implementation:* As described in previous sections active participation of the users in the design process was encouraged through audit and feedback, and wider inputs from workshops and surveys.

Challenges and Next steps

We would emphasize that the role of MATE or any similar IT system is purely supportive and the MDT meeting continues to be led by the clinical team. Advanced IT systems can only complement an effective and functional multidisciplinary team,[18] and cannot compensate for inherent weaknesses in team composition, organisation or operation. The preliminary audit results and the qualitative assessment data reported in this study, however encouraging, are at this point indicative of the potential benefits but not yet conclusive. They should be treated with caution until further rigorous evaluations confirm the effectiveness and generalisability of MATE or similar services.

Generalisability:

It is has been reported that clinical decision support systems are often at their best when the developing team is involved in the trial of the system. One review reported for example that the success rate for clinical decision support systems dropped from 74% to 28% when the systems were tested by independent teams.[19] The team involved in the development of MATE was also involved in testing and the deployment of the system so replication of our results on other sites is a key objective. Demonstrating that MATE can confer significant benefits for other cancer MDTs is also a high priority. MATE has attracted the attention of the UK Department of Health's National Cancer Action Team and deployment of the system in other NHS trusts is being explored.

Effectiveness trials:

Definitive evidence of the value of complex (multifaceted) interventions such as MATE requires a multi-centre trial in which a cluster randomised design is likely to be the preferred methodology.[20] The trial should look into all important impacts of the intervention including quantitative measures of cost, patient outcomes and process measures as well as qualitative measures.

Patient empowerment:

Patient involvement in decisions about their treatment is widely considered to be crucial to improving outcomes and many cancer patients wish to play a more active role in their care. The current structure of the cancer MDT meeting makes patient participation very difficult to achieve.[21] We are therefore exploring ways in which MATE could facilitate patient engagement, by extending access to certain of its functions by the patients, in a variety of settings, including consultations in results clinic and from home, allowing the patients to review their clinical history, and the MDT recommendations and explanations for the recommendations.

Ethics approval

Ethics approval was not required for the submitted work however for the subsequent randomised controlled trial, which is ongoing, ethics approval was taken from the Moorfields & Whittington Research Ethics Committee.

Competing interest

All authors have completed the Unified Competing Interest form and declare that (1) None of the authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) [VP, DA, JF, MK] have following specified non-financial interests that may be relevant to the submitted work.
UCL(B): a subsidiary of University College London and ISIS innovation: a subsidiary of the University of Oxford, are actively looking to commercialise aspects of this project in the form of a spin-out company.

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Contributorship statement:

All authors have made substantial contributions as follow
VP, JF and MK: conception and design;
VP, DA, TD, AJ and MK: Conducting the pilot study
VP and DA: developing the system, acquisition of data,
VP and MK: analysis and interpretation of data;
VP, DA, JF, MK: drafting the article;
All authors: revising it critically for important intellectual content;
All authors: final approval of the version to be published.

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Table 1. Pragmatic challenges for cancer MDT meetings

1. Ensuring and documenting adherence with standards (e.g. evidence-based guidelines)
2. Identifying patients who are eligible for recruitment into clinical trials
3. Ensuring the consistent collection of crucial data such as disease staging and outcomes
4. Establishing robust mechanisms for prospective assessment of MDT performance
5. Ensuring MDT recommendations are followed in practice
6. Achieving the right balance of educational and care delivery objectives of this forum
7. Establishing reliable interfaces with primary care to ensure continuity of care

Figure 1. MATE in use at Royal Free breast MDT meeting.

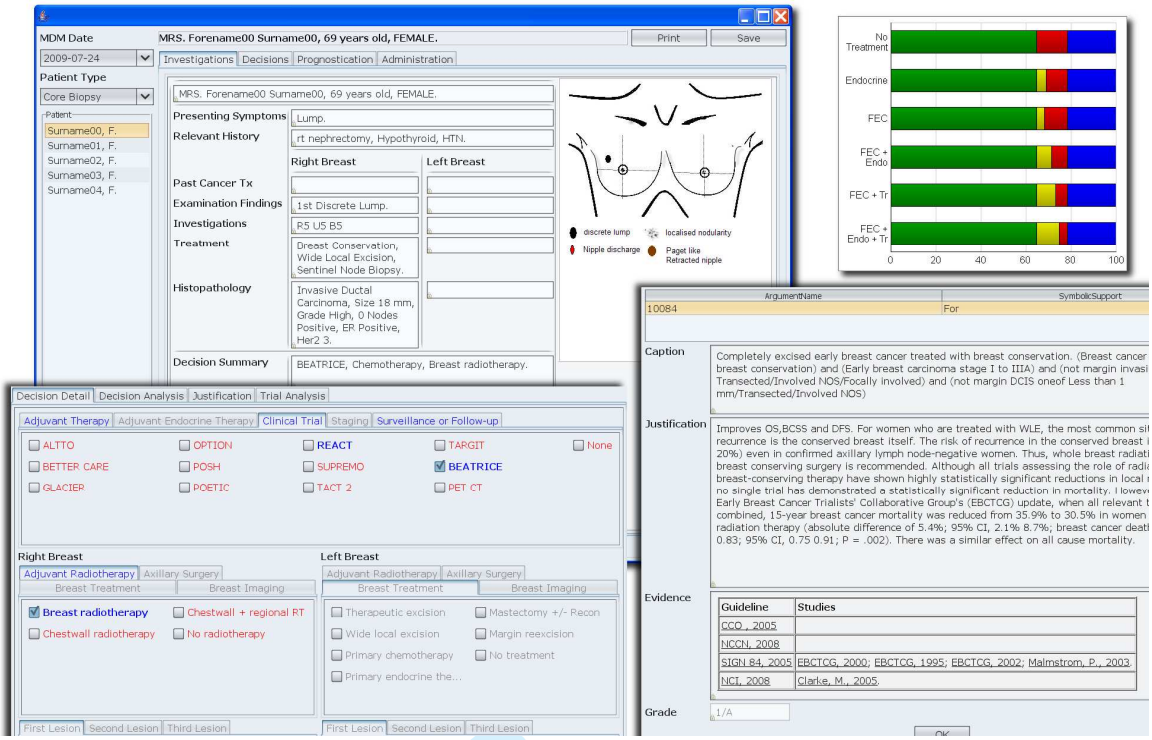

Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Pathology	Number
Benign breast disease	413
Operable breast cancer (in situ and invasive)	511
No final diagnosis reached (e.g. C1/C3/C4 on cytology or B1/B3/B4 on core biopsy) at the time of MDT meeting	132
Metastatic and or recurrent cancers	198
Other than breast epithelial malignancies	41
Total cases	1295

Table 2. Distribution of breast cases discussed at MDM according to type

Improving cancer multi-disciplinary meetings: A pilot study of advanced clinical decision support technology

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- Pilot evaluation results

Key messages:

- An advanced CDS platform could significantly improve the conduct of cancer MDT meetings.

- Further robust evaluations are necessary.

Strengths and limitations:

- We share our valuable experience of developing an advanced decision support system and implementing in a complex clinical environment of cancer MDT which is subsequently adopted as a breast MDT meetings management tool.

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Abstract:

Objectives: The cancer multidisciplinary team (MDT) meeting is regarded as the best platform to reduce unwarranted variation in cancer care through evidence-compliant management. However, MDT meetings are often overburdened with many different agendas, and hence struggle to achieve their full potential. We developed an interactive clinical decision support system called MATE (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), to facilitate explicit, evidence-based decision making in the breast MDT meetings and to improve the overall conduct.

Design: Audit study and a questionnaire survey.

Setting: Breast multidisciplinary unit in a large secondary care teaching hospital.

Participants: The participants included all members of the breast MDT at the Royal Free Hospital, London. The emphasis was on active user participation through audit, feedback and response, acknowledging the clinical needs and practical constraints of the MDT and fitting the system around the team's work-flow rather than the other way around.

Outcome measures: The measures included evidence compliant care; measured by adherence to clinical practice guidelines (CPGs) and promoting research; measured by the patient identification rate for ongoing clinical trials.

Results: MATE identified 61% more patients who were eligible for recruitment into clinical trials than the MDT and MATE recommendations demonstrated better concordance with CPG than MDT recommendations (97 of MATE vs 93.2 % of MDT; N = 984). MATE is in routine use in breast MDT meetings at Royal Free hospital, London and wider evaluations are being explored.

Conclusions: Sophisticated decision support systems can enhance the conduct of MDT meetings in a way that is acceptable to and valued by the clinical team. Further rigorous evaluations are required to examine cost-effectiveness and measure the impact on patient outcomes. The decision support technology used in MATE is generic and if found useful can be applied across the medicine.

~~**Problem** The cancer multidisciplinary team (MDT) meeting is regarded as the best platform to reduce unwarranted variation in cancer care through evidence-compliant~~

Comment [vivek1]: R2: The authors may wish to expand the acronym MATE in the abstract – as this is what many readers will be able to read on the front page of BMJ

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Problem statement

Unwarranted practice variation across different medical domains has unfortunately become a pervasive finding in health service research and breast cancer care is no exception.[1] A recently published study reported significant differences in breast cancer survival across hospitals in the same geographical region in England.[2] The reasons for

practice variation are multifactorial and standardisation of care has been attempted by the introduction of Regional Cancer Networks in England and the adoptions of the Multi Disciplinary Team (MDT) model to promote maximal adoption of evidence-based practice. The MDT model is increasingly being adopted in other non-cancer medical domains such as stroke, cardiovascular diseases and diabetes.

Many benefits of MDTs have been claimed, but few have been backed by strong evidence.[3,4] However, despite a significant lack of prospective evidence, MDTs are well accepted in clinical practice; they are regarded as a major advance in management of cancer patients and their use appears to be increasing.[5] As many health care systems have already committed to and invested in the MDT model, further reductions in unwarranted variation are likely to be best achieved by improving their conduct and standardizing their decision making processes.[6] Data collected by the UK national cancer peer review programme from over 1000 teams across six cancer types in England indicates that there is significant room for improvement in the conduct of MDT meetings. ~~The analysis reported by Taylor et al,~~ and shows considerable variability in the performance of MDTs.[7] A recent national survey of more than 2000 members of cancer multidisciplinary teams, demonstrated agreement on the range of criteria necessary for effective MDT working.[3] A review of the literature by the authors identified many pragmatic challenges and shortcomings in the current conduct of cancer MDT meetings summarised in Table 1.[8]

Comment [vivek2]: R2: In the problem statement you may wish to mention that MDT meetings are no longer solely seen in cancer patients and they are becoming much more common in complex surgical care, cardiovascular disease, transplant and other clinical domains

Context

The Royal Free Hospital NHS Trust (RFH) serves a population of 2.6 million within the North London Cancer Network (NLCN) catchment area. The number of new patients (both benign and cancer) seen as outpatients by the breast unit in 2009-10 was 2,944. The Breast Cancer Multidisciplinary team at RFH was established in 2005, in line with the recommendations of the NHS Cancer Plan. The MDT uses a set of NLCN-approved clinical guidelines and a standardized minimum data set.

MDT meetings (MDM) are held every week in a conventional conference format. The core members of a breast MDT include breast surgeons, radiologists, pathologists,

medical and clinical oncologists, plastic surgeons and breast care nurses. A typical breast MDM discusses an average of 30 to 40 patients at various stages in their care pathways every week to decide further courses of action.

Prior to the introduction of our computer-based service into the MDT meetings, an entirely paper based record system was used to provide case summaries and to document the MDT's discussion and decisions. These records contained free (unstructured) text rather than the coded and structured data ~~used by a modern electronic health record (EHR)~~. The tradeoffs between structured (computer interpretable) and unstructured (free text clinical notes , scanned documents, pdfs) EHRs are well known.[9] MDT discussion records in an unstructured form, hinders the process of accurate measurement of MDT performance as computer based data analysis and auditing tools can not be used on unstructured data.

~~The main drawbacks of an unstructured MDT record are that it hinders attempts to accurately measure the performance of the MDT and provision of automated data analysis processes and implementation of alerts and reminders, and decision support etc.~~

There are many commercially available information and communication systems such as EHR systems which can assist in the preparation, presentation and documentation of cases at the MDT meetings. However the objectives of our MDT service improvement exercise was to go beyond improvements in data management by providing active support for evidence-based decision making, improving recruitment into clinical trials and supporting prospective audit.[10]

Comment [vivek3]: On page 8 of 19 (according to the pdf) in the paragraph starting "Prior to the introduction of our…" – the last sentence is written poorly and ends with etc – this doesn't make sense and some thought needs to be given to rewriting these points more clearly.–

Measures of improvement

Evidence compliant care: Adherence with clinical practice guidelines

With the increasing recognition of shortcomings in healthcare systems, there is a significant cultural and professional shift towards using evidence-based guidance. Evidence-based standards of care, such as published practice guidelines and technology assessment reports developed by authoritative organisations provide an objective standard against which to assess MDT decisions. There is growing evidence that use of evidence-based guidelines can improve patient outcomes,[11-13] and MDT meetings

provide the best opportunity to actively promote an *appropriate* and *judicious* use of the guidelines at the point of care.

Promoting research: Identification of patients eligible for ongoing research trials

It is widely accepted that recruiting patients into clinical trials is an effective strategy for ensuring that cancer patients get the best care as well as providing important information about the efficacy of treatments. However, the literature continues to report low rates of accrual to cancer clinical trials,[14] and many organisations at national and international levels are investigating strategies for improving accrual rates. Cancer MDT meetings represent a major opportunity for identifying patients who are eligible for participation in clinical trials.[15]

Methods

In order to assess the performance of the breast MDT on the above mentioned measures we developed a computerised decision support system, **MATE** (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), that captures patient data, identifies eligible patients for clinical trials and suggests evidence-based treatment recommendations. MATE also captures MDT decisions and hence can automatically compare them with guideline recommendations.

System development

We followed a systematic, stepwise approach throughout the system development lifecycle. Requirements for MATE were identified through a systematic review of the literature and by working closely with members of the breast MDT at RFH. We adopted the CommonKADS methodology to develop a comprehensive process and knowledge model for breast cancer MDT meetings.[16] A controlled vocabulary from National Cancer Institute thesaurus [17] was used to facilitate data standardisation. The evidence sources reviewed included Clinical Practice Guidelines, Systematic Reviews and Meta-analyses and reports of Randomised Controlled trials. Along with the guideline recommendations, the eligibility criteria of ongoing clinical trials in breast cancer that

Comment [vivek4]: R2 Readers may be interested to know what controlled vocabulary was used

were open for the recruitment at our institution were also coded into the system. PRO*forma*,[18] a decision modelling language for formalising clinical decisions and care pathways, was used for the formal evidence representation in MATE. The PRO*forma* language and application development software Tallis used in this project were originally developed at Cancer Research UK; Tallis is now being developed at Oxford University. Tallis was used to implement a range of decision support and other services[1] as determined by the requirements development process outlined above, and is used to update recommendations and other components of the PRO*forma* knowledge base when new guidance is published.

System description

MATE functionality can be categorised into two broad labels: 1. Structured data capture, presentation and audit modules 2. Advanced evidence-based decision support module

Data capture: MATE allows user to capture detailed structured clinical data including, demographics, co morbidities, test results, clinical findings, imaging, pathology and treatment related data. The data is entered in the system either before (preparation phase) or during the MDT meetings (presentation phase). In the preparation phase the data is entered by a clinician, who is responsible for the preparation of the meeting. The data entry is flexible, quick and secure and it was found to save the preparation time. If some of the test results such as pathology report are not available before the MDT meeting, they could easily be entered in MATE during the meeting by a clinician in charge, without delaying the proceedings. MATE also provides automatic summary generation and prospective audit facilities.

Advanced evidence-based decision support module: is the key component of MATE which sets it apart from cancer tracking systems, EHR systems and the first generation rule based alert or reminder systems. MATE actively evaluates diagnostic markers histo-pathological data and other patient related factors such as co-morbidities to generate

[1] http://mate.cossac.org/

Comment [vivek5]: R2: summarised clinical description of the system may be warranted and

R1: It is not entirely clear upon what information the recommendations of MATE are based upon - is it simply on diagnostic markers (radiology/hisotology) or does it take account of any patient-based factors (demographics, co-morbidities, preferences of patients etc?). Blazeby's work has shown that failure to consider such information is a major reason for non-implementation of recommendations (assocated with delays to treatment etc). Could this system work for complex cases or is it mostly for 'routine' cases? If so could one benefit of such a system be to help MDTs to prioritise cases according to their complexity - ensuring that more time is spent on complex cases and that the routine case that are protocol led are instead agreed consensually to be such?
Can the system come up with a ranking of options for example - whereby if the fitness of the patient is in question or they refuse a recommendation for any reason it can determine the next best in terms of evidence?

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patient specific recommendations for the management. An advanced PRO*forma* decision support technology enables MATE to rank the recommended options: for example - if the fitness of the patient is in question due to co-morbidity, MATE can recommend the next best option in terms of evidence. In principle, patient preferences could also be factored in to the MATE decision model and we are actively exploring the ways of supporting patient preferences as discussed in the last section under heading patient empowerment. The recommendations are presented to the user in the form of arguments, linked to the supporting evidence, for ~~the~~ transparency. MATE knowledge base consisted of a comprehensive set of published national and international clinical practice guidelines, which enables MATE to provide recommendations even in complex cases that are covered by these guidelines. MATE also provides quantitative risk estimates based on published models as an adjunct to the recommendations. The user interface of MATE is illustrated in Fig 2. The detailed description of the knowledge base, technology and architecture is published elsewhere[2] [19].

We used the following processes to understand and analyse the design issues and to feed back clinical experience into the MATE development lifecycle.

Evaluation phase

MATE was used to prospectively record the proceedings of breast MDT meetings between April 2008 and July 2009 to gather 1,295 cases discussed in the MDMs during this period. An ~~A~~appropriate ~~ethics and R & D~~ approval~~s~~ for an audit study from Research and Development department of the hospital ~~were~~ was obtained before starting the study, and data-security measures such as encryption were put in place. MATE allows us to capture both patient data and MDT decisions in a structured form. MATE records were cross-checked with the official MDM record sheets and, in case of any discrepancies, the MATE record was corrected to reflect the official MDM record.

Comment [vivek6]: R1: Can the system come up with a ranking of options for example - whereby if the fitness of the patient is in question or they refuse a recommendation for any reason it can determine the next best in terms of evidence?

Comment [vivek7]: R1: appropriate ethics and r&d were obtained, but p15 states ethics approval was not required. This needs further explanation - how was patient data obtained/stored/analysed in order to avoid requiring ethics approval?

[2] Acosta, D. et al., 2010. Challenges in Delivering Decision Support Systems: The MATE Experience. In *Knowledge Representation for Health-Care. Data, Processes and Guidelines*. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, pp. 124-140. Available at: http://dx.doi.org/10.1007/978-3-642-11808-1_11.

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One of the key distinctive features of MATE compared to a traditional electronic health record is the clinical decision support (CDS) element. MATE is able to evaluate patient data and to *actively* offer guideline-based recommendations in real time which are specific for each individual patient. We used MATE to compare *the actual MDT decisions* to that of *guideline recommendations.*

The discordant cases (where MATE recommendations differed from those of MDT decisions) were further investigated by a panel who reviewed the patient's clinical notes. MATE also automatically flags patients who meet eligibility criteria for ongoing clinical trials.

Structured feedback

The MATE development team was invited to conduct a workshop at the England Cancer Networks' Development Programme conference in March 2010, The conference was attended by key members from all cancer networks, who are instrumental in governing and improving MDT conduct in their respective cancer networks. MATE was demonstrated in the workshop and a questionnaire survey was conducted at the end of the presentation and discussion session.

Results

Evaluation phase results

A total of 1,295 breast cases were recorded on MATE between April 2008 and July 2009 (each time a patient was discussed in the MDT meeting was counted as a separate encounter). The case mix included cancers and benign pathologies. Table 2 shows the overall distribution of cases recorded on the MATE system during the study system. Metastatic, recurrent and non epithelial malignancies were excluded from the guideline concordance analysis as the guidelines and evidence-base for those subsets were not initially coded in MATE. In 239 cases of recurrent, metastatic or non-epithelial malignancies, MATE therefore provided data capture services but no decision support. The remaining 1056 cases were analysed for concordance between management

recommendations made by MATE and the actual MDT decisions and the level of concordance was encouragingly high (93.2 %; N = 984). When the 6.8 % discordant cases were further analysed it was found that in 3.2% cases, ~~of~~ the MDT deviant decisions were corrected by the treating clinician in the results clinic.

MATE also identified 61% more patients who were eligible for the recruitment into clinical trials than the MDT alone. To note that MATE only screens the patients as possibly eligible for the trials, based on the main eligibility criteria. All the information needed before recruiting the patient is often not available to the MDT. Certain tests specific for the trial (e.g. 2D Echo for ejection fraction) are done after MDT discussion and the results are not available at the MDM.

Structured Feedback

The MATE workshop at the Cancer Networks' Development Programme conference was attended by 54 people, of whom 48 completed the questionnaire. ~~Most respondents (95.8%) agreed that clinical decision support has a useful role in cancer MDMs. The majority of respondents found the services provided by MATE useful for the breast MDM (93.47) and potentially for other types of cancer MDMs (92.6%).~~ The roles of respondents were categorised as follows

Clinicians (Doctors & Nurses) = 13

Patients/survivors = 5

Service improvement managers = 18

Informaticians = 7

Others = 5

Respondents were asked to select from a choice of 5 categories (strongly agree, agree, neutral, disagree, strongly disagree) for five structured questions regarding usefulness of the system. They were also asked open ended questions to find any perceived barriers and their general comments. For the analysis we combined "strongly agree or agree" responses as "agree" category and "neutral, disagree or strongly disagree" responses as disagree category. The "neutral" category was included in disagree to ensure a conservative interpretation.

Comment [vivek8]: is it 3.2% of the 7% of discordant cases or3.2% of decisions? this is not clear. Also what does it mean that 'decisions were 'corrected' by the treating clinician in the results clinic'. Does this mean that the MDT recommendation was not protocol led and was 'corrected' to be so in the clinic (i.e. MATE was 'right')?

Comment [vivek9]: R1: was eligibility for trial recruitment checked in terms of the factors that are not considered by MATE (fitness, comoribidities etc)? If not then this figure could be an inflation of the percentage over and above the team recommendations for trials.

R2: Assuming that MATE was used in the context of the current MDM,– this would mean that the effect of change should perhaps read "MATE identified 61% more patients who were eligible for recruitment into clinical trials than the MDT alone

Comment [vivek10]: R1: I do not understand: 'the need for practical knowledge validation and maitenance mechanisms' - suggest this may need rewording/explaining

R2:
The weakest area of the paper is the description and reporting of the data from the questionnaire survey where there is little description of methodology and must be open to bias. Providing data to one significant figure from 48 questionnaires without any indication about the content or methods of the questionnaire is dubious

There was very high consensus over the usefulness of clinical decision support in general, and MATE in particular, for cancer MDT meetings. Most respondents (95.8%) agreed that clinical decision support has a useful role in cancer MDMs. The majority of respondents found the services provided by MATE useful for the breast MDM (93.47) and potentially for other types of cancer MDMs (92.6%). The clinical decision support component and ability to automatically screen patients for ongoing clinical trials were seen as the two most valuable capabilities of MATE by the majority of respondents (84.5% and 81.2% of respondents respectively). Other capabilities of MATE , identified as valuable were patient data capture (70% of respondents), clinical audit services (67%), peer review support (58%) and education/training (45%). The majority of respondents (73.8%) were favourable to recommending MATE, if it were made available in their network.

The survey also identified important barriers to large-scale deployment of MATE. The main perceived obstacle to adoption was double data entry (50%) in situations where existing data capture systems are in place and it was suggested that MATE should be able to interface with existing data capture systems. Other barriers identified were costs and resources, clinical buy-in, scalability and the need for ~~practical knowledge validation and~~scalable knowledge maintenance mechanisms.

Strategies for change and effects

The encouraging performance of MATE in this initial phase established the confidence of the breast team at RFH, and MATE was subsequently introduced as the standard breast MDM management tool. Introducing a new technology into as complex a setting as the cancer MDM was a challenging task and our implementation strategy was guided by the experiences of others reported in the literature.[20, 21]

The principles of the implementation strategy for MATE are summarised as follows.

- *Building around the existing clinical work-flow:* In order to ensure the clinical acceptability of MATE, a key design objective was to fit the system around the existing work-flow of the breast MDM and not the other way round.

- *Anticipating clinical needs and pragmatic constraints:* As well as obvious requirements such as access to detailed patient data, a number of other useful services were identified during the modelling phase (e.g. quick access to past MDT decisions).
- *Active involvement of users throughout audit, feedback and implementation:* As described in previous sections active participation of the users in the design process was encouraged through audit and feedback, and wider inputs from workshops and surveys.

Challenges and Next steps

We would emphasize that the role of MATE or any similar IT system is purely supportive and the MDT meeting continues to be led by the clinical team. Advanced IT systems can only complement an effective and functional multidisciplinary team,[22] and cannot compensate for inherent weaknesses in team composition, organisation or operation. The preliminary audit results and the qualitative assessment data reported in this study, however encouraging, are at this point indicative of the potential benefits but not yet conclusive. They should be treated with caution until further rigorous evaluations confirm the effectiveness and generalisability of MATE or similar services.

Generalisability:

It is has been reported that clinical decision support systems are often at their best when the developing team is involved in the trial of the system. One review reported for example that the success rate for clinical decision support systems dropped from 74% to 28% when the systems were tested by independent teams.[23] The team involved in the development of MATE was also involved in testing and the deployment of the system so replication of our results on other sites is a key objective. Demonstrating that MATE can confer significant benefits for other cancer MDTs is also a high priority. MATE has attracted the attention of the UK Department of Health's National Cancer Action Team and deployment of the system in other NHS trusts is being explored.

Effectiveness trials:

Definitive evidence of the value of complex (multifaceted) interventions such as MATE requires a multi-centre trial in which a cluster randomised design is likely to be the preferred methodology.[24] The trial should look into all important impacts of the intervention including quantitative measures of cost, patient outcomes and process measures as well as qualitative measures.

Patient empowerment:

Patient involvement in decisions about their treatment is widely considered to be crucial to improving outcomes and many cancer patients wish to play a more active role in their care. The current structure of the cancer MDT meeting makes patient participation very difficult to achieve.[25] We are therefore exploring ways in which MATE could facilitate patient engagement, by extending access to certain of its functions by the patients, in a variety of settings, including consultations in results clinic and from home, allowing the patients to review their clinical history, and the MDT recommendations and explanations for the recommendations.

Ethics approval

Ethics approval was not required for the submitted work however for the subsequent randomised controlled trial, which is ongoing, ethics approval was taken from the Moorfields & Whittington Research Ethics Committee.

Competing interest

All authors have completed the Unified Competing Interest form and declare that (1) None of the authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) [VP, DA, JF, MK] have following specified non-financial interests that may be relevant to the submitted work.
UCL(B): a subsidiary of University College London and ISIS innovation: a subsidiary of the University of Oxford, are actively looking to commercialise aspects of this project in the form of a spin-out company.

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Contributorship statement:
All authors have made substantial contributions as follow
VP, JF and MK: conception and design;
VP, DA, TD, AJ and MK: Conducting the pilot study
VP and DA: developing the system, acquisition of data,
VP and MK: analysis and interpretation of data;
VP, DA, JF, MK: drafting the article;
All authors: revising it critically for important intellectual content;
All authors: final approval of the version to be published.

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Table 1. Pragmatic challenges for cancer MDT meetings

1. Ensuring and documenting adherence with standards (e.g. evidence-based guidelines)
2. Identifying patients who are eligible for recruitment into clinical trials
3. Ensuring the consistent collection of crucial data such as disease staging and outcomes
4. Establishing robust mechanisms for prospective assessment of MDT performance
5. Ensuring MDT recommendations are followed in practice
6. Achieving the right balance of educational and care delivery objectives of this forum
7. Establishing reliable interfaces with primary care to ensure continuity of care

Figure 1. MATE in use at Royal Free breast MDT meeting.

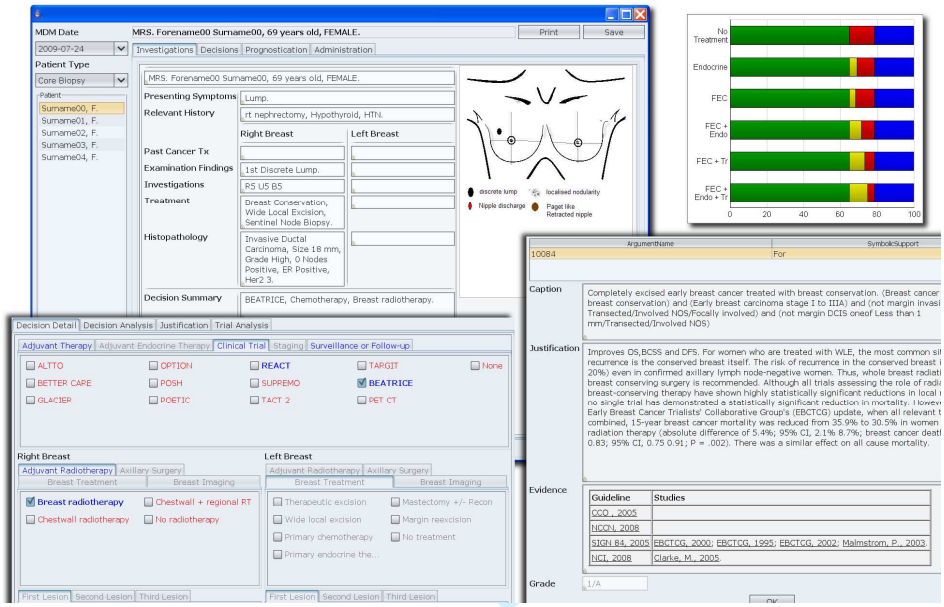
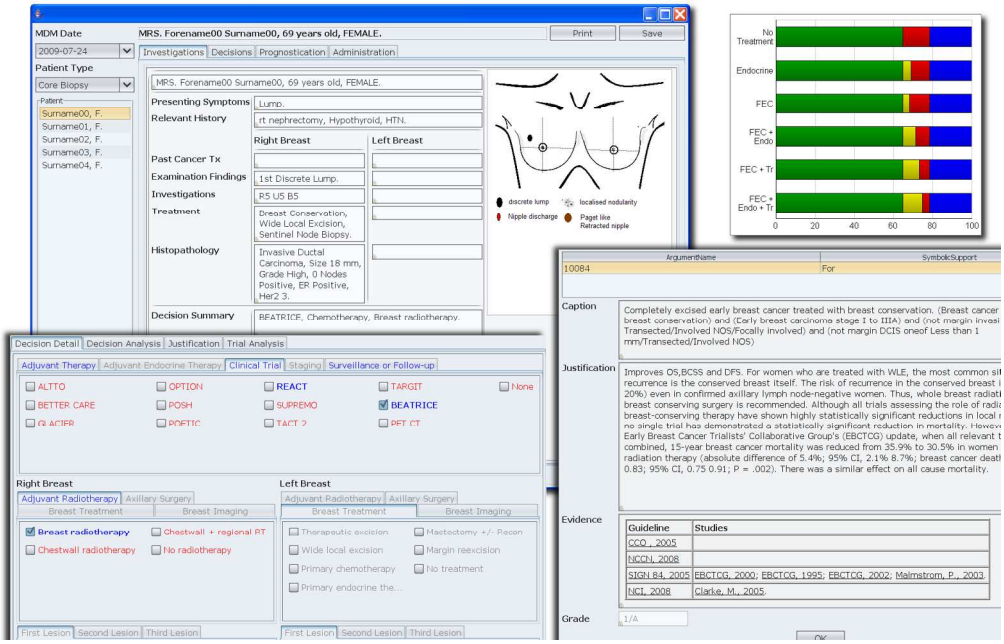


Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Pathology	Number
Benign breast disease	413
Operable breast cancer (in situ and invasive)	511
No final diagnosis reached (e.g. C1/C3/C4 on cytology or B1/B3/B4 on core biopsy) at the time of MDT meeting	132
Metastatic and or recurrent cancers	198
Other than breast epithelial malignancies	41
Total cases	1295

Table 2. Distribution of breast cases discussed at MDM according to type

Figure 1. MATE in use at Royal Free breast MDT meeting.
454x165mm (300 x 300 DPI)



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BMJ open

Using computerised decision support to improve compliance of cancer multidisciplinary meetings with evidence-based guidance

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Figure 1. MATE in use at Royal Free breast MDT meeting.
454x165mm (300 x 300 DPI)

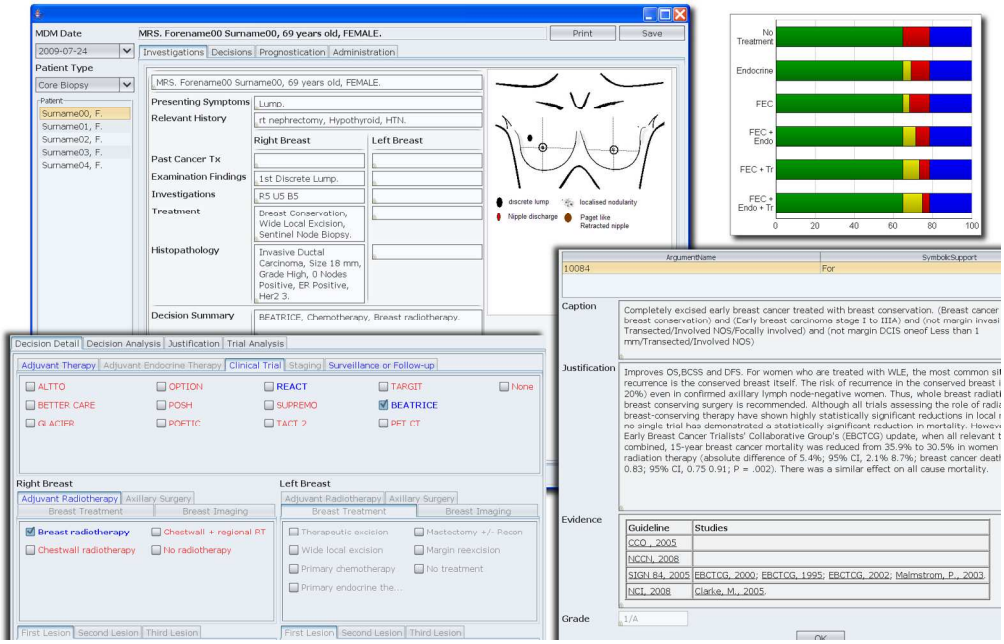

Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Using computerised decision support to improve compliance of cancer multidisciplinary meetings with evidence-based guidance

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Comment [v1]: Reviewer: It would be helpful if the research question/s were explicitly stated. The title is broad 'improving meetings' and conduct of meetings is mentioned as an aim but this is not measured - the focus seems to be on the concordence of MATE recommendations with MDT recommendations and recruitment into trials, with some estimate of acceptability of it but taken from a workshop not the actual users. Suggest clarifying the research questions would add structure to the paper. Title and article focus should possibly be revised in line with this

Article summary

Article focus:

- How to improve the conduct of a cancer MDT and standardize decision-making in accordance with best evidence
- Development and implementation of a novel clinical decision support (CDS) platform for breast cancer MDT
- ~~Pilot~~ This study evaluates a) the concordance between the CDS suggestions and MDT recommendations; and b) the identification rate of potentially eligible patients for recruiting into the ongoing research trials, by the MDT and the CDS. A separate questionnaire survey was conducted at the national workshop at the Cancer Networks' Development Programme to get an estimate of acceptability of such MDT decision support systems by the cancer networks. ~~evaluation results~~

Comment [v2]: Reviewer t would be helpful if the research question/s were explicitly stated. The title is broad 'improving meetings' and conduct of meetings is mentioned as an aim but this is not measured - the focus seems to be on the concordance of MATE recommendations with MDT recommendations and recruitment into trials, with some estimate of acceptability of it but taken from a workshop not the actual users. Suggest clarifying the research questions would add structure to the paper. Title and article focus should possibly be revised in line with this.

Key messages:

- An advanced CDS platform could significantly improve the conduct of cancer MDT meetings.
- Further robust evaluations are necessary.

Strengths and limitations:

- We share our ~~valuable~~ experience of developing an advanced decision support system and implementing it in a complex clinical environment of cancer MDT which ~~is~~ was subsequently adopted as a breast MDT meetings management tool.
-The results reported here, however encouraging, are at this point indicative of the potential benefits but not yet conclusive. They should be treated with caution until further rigorous evaluations confirm the effectiveness and generalisability of the CDS system.

Data sharing statement:

There is no additional data available.

Research checklist:

Appropriate research checklist could not be found.

Abstract:

Objectives: The cancer multidisciplinary team (MDT) meeting is regarded as the best platform to reduce unwarranted variation in cancer care through evidence-compliant management. However, MDT meetings are often overburdened with many different agendas, and hence struggle to achieve their full potential. We developed an interactive clinical decision support system called MATE (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), to facilitate explicit, evidence-based decision making in the breast MDT meetings and to improve the overall conduct of the meeting.

Design: Audit study and a questionnaire survey.

Setting: Breast multidisciplinary unit in a large secondary care teaching hospital.

Participants: The participants included all members of the breast MDT at the Royal Free Hospital, London. The emphasis was on active user participation through audit, feedback and response, acknowledging the clinical needs and practical constraints of the MDT and fitting the system around the team's work-flow rather than the other way around.

Outcome measures: The ~~measures included~~measures included evidence compliant care; measured by adherence to clinical practice guidelines (CPGs) and promoting research; measured by the patient identification rate for ongoing clinical trials.

Results: MATE identified 61% more patients who were potentially eligible for recruitment into clinical trials than the MDT and MATE recommendations demonstrated better concordance with CPG than MDT recommendations (97% of MATE vs 93.2 % of MDT; N = 984). MATE is in routine use in breast MDT meetings at the Royal Free hospital, London and wider evaluations are being ~~explored~~considered.

Conclusions: Sophisticated decision support systems can enhance the conduct of MDT meetings in a way that is acceptable to and valued by the clinical team. Further rigorous evaluations are required to examine cost-effectiveness and measure the impact on patient outcomes. The decision support technology used in MATE is generic and if found useful can be applied across ~~the~~ medicine.

Problem statement

Unwarranted practice variation across different medical domains has unfortunately become a pervasive finding in health service research and breast cancer care is no exception.[1] A recently published study reported significant differences in breast cancer survival across hospitals in the same geographical region in England.[2] The reasons for practice variation are multifactorial and standardisation of care has been attempted by the introduction of Regional Cancer Networks in England and the adoption of the Multi Disciplinary Team (MDT) model to promote maximal adoption of evidence-based practice. The MDT model is increasingly being adopted in other non-cancer medical domains such as stroke, cardiovascular diseases and diabetes.

Many benefits of MDTs have been claimed, but few have been backed by strong evidence.[3,4] However, despite a significant lack of prospective evidence, MDTs are well accepted in clinical practice; they are regarded as a major advance in management of cancer patients and their use appears to be increasing.[5] As many health care systems have already committed to and invested in the MDT model, further reductions in unwarranted variation are likely to be best achieved by improving their conduct and standardizing their decision making processes.[6] Data collected by the UK national cancer peer review programme from over 1000 teams across six cancer types in England indicates that there is significant room for improvement in the conduct of MDT meetings and shows considerable variability in the performance of MDTs.[7] A recent national survey of more than 2000 members of cancer multidisciplinary teams, demonstrated agreement on the range of criteria necessary for effective MDT working.[3] A review of the literature by the authors identified many pragmatic challenges and shortcomings in the current conduct of cancer MDT meetings summarised in Table 1.[8]

Context

The Royal Free Hospital NHS Trust (RFH) serves a population of 2.6 million within the North London Cancer Network (NLCN) catchment area. The number of new patients (both benign and cancer) seen as outpatients by the breast unit in 2009-10 was 2,944.

The Breast Cancer Multidisciplinary team at RFH was established in 2005, in line with the recommendations of the NHS Cancer Plan. The MDT uses a set of NLCN-approved clinical guidelines and a standardized minimum data set.

MDT meetings (MDM) are held every week in a conventional conference format. The core members of a breast MDT include breast surgeons, radiologists, pathologists, medical and clinical oncologists, plastic surgeons and breast ~~care nurses~~clinical nurse specilaists. A typical breast MDM discusses an average of 30 to 40 patients at various stages in their care pathways every week to decide further courses of action in their management.

Prior to the introduction of our computer-based service into the MDT meetings, an entirely paper based record system was used to provide case summaries and to document the MDT's discussion and decisions. These records contained free (unstructured) text rather than ~~the~~ coded and structured data. The tradeoffs between structured (computer interpretable) and unstructured ~~(free text clinical notes , scanned documents, pdfs)~~ EHRs are well known.[9] Recording MDT discussions ~~records~~ in an unstructured form such as free text clinical notes, scanned documents, pdfs etc, hinders the process of accurate measurement of MDT performance as computer based data analysis and auditing tools cannot be used on unstructured data.

There are many commercially available information and communication systems ~~such as EHR systems~~ which can assist in the preparation, presentation and documentation of cases at the MDT meetings such as EHR systems. However the objectives of our MDT service improvement exercise was to go beyond improvements in data management by providing active support for evidence-based decision making, improving recruitment into clinical trials and supporting prospective audit.[10]

Measures of improvement

Evidence compliant care: Adherence with clinical practice guidelines

With the increasing recognition of shortcomings in healthcare systems, there is a significant cultural and professional shift towards using evidence-based guidance. Evidence-based standards of care, such as published practice guidelines and technology

assessment reports developed by authoritative organisations, provide an objective standard against which to assess MDT decisions. There is growing evidence that use of evidence-based guidelines can improve patient outcomes,[11-13] and MDT meetings provide the best opportunity to actively promote an *appropriate* and *judicious* use of the guidelines at the point of care.

Promoting research: Identification of patients eligible for ongoing research trials

It is widely accepted that recruiting patients into clinical trials is an effective strategy for ensuring that cancer patients get the best care as well as providing important information about the efficacy of treatments. However, the literature continues to report low rates of accrual to cancer clinical trials[14] and many organisations at national and international levels are investigating strategies for improving accrual rates. Cancer MDT meetings ~~represent~~ offer a major opportunity for identifying patients who are eligible for participation in clinical trials.[15]

Methods

In order to assess the performance of the breast MDT on the above mentioned measures we developed a computerised decision support system, **MATE** (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), that captures patient data, identifies eligible patients for clinical trials and suggests evidence-based treatment recommendations. MATE also captures MDT decisions and hence can automatically compare them with guideline recommendations.

System development

We followed a systematic, stepwise approach throughout the system development lifecycle. Requirements for MATE were identified through a systematic review of the literature[16] and by working closely with members of the breast MDT at RFH. We adopted the Common KADS methodology to develop a comprehensive process and knowledge model for breast cancer MDT meetings.[17] A controlled vocabulary from the National Cancer Institute thesaurus [18] was used to facilitate data standardisation. The

Comment [v3]: Riviewer A systematic review is mentioned but no further details given - review of what literature? is this described/published elsewhere?

evidence sources reviewed included Clinical Practice Guidelines, Systematic Reviews and Meta-analyses and reports of Randomised Controlled trials. Along with the guideline recommendations, the eligibility criteria of ongoing clinical trials in breast cancer that were open for ~~the~~ recruitment at our institution were also coded into the system.

PRO*forma*,[19] an established decision modelling language for ~~formalising~~ modelling clinical decisions and care pathways, was used ~~for the formal evidence~~ to formalise decisions and supporting evidence ~~representation~~ in MATE. The PRO*forma* language and application development software Tallis used in this project were originally developed at Cancer Research UK. ~~Tallis is now being developed at Oxford University.~~ Tallis was used to implement a range of decision support and other services[1] as determined by the requirements development process outlined above, and is used to update recommendations and other components of the PRO*forma* knowledge base when new guidance is published. Tallis is being developed jointly by Oxford University and the Royal Free development team.

System description

MATE functionality can be categorised ~~into~~ under two broad ~~labels~~headings: 1. Structured data capture, presentation and audit ~~modules~~ 2. Advanced evidence-based decision support ~~module~~

Data capture: MATE allows users to capture detailed structured clinical data including, demographics, co morbidities, test results, clinical findings, imaging, pathology and treatment related data. The data are entered into the system either before (preparation phase) or during the MDT meetings (presentation phase). In the preparation phase the data are entered by a clinician, who is responsible for the preparation of the meeting. D~~The d~~ata entry is flexible, quick and secure and it was found to ~~save~~ reduce preparation time. If some of the test results such as pathology reports are not available before the MDT meeting, they can easily be entered in MATE during the meeting by a clinician ~~in~~

[1] http://mate.cossac.org/

charge, without delaying the proceedings. MATE also provides patient summaries automatically summary generation and prospective audit facilities.

Advanced evidence-based decision support module: is the key component of MATE which sets it apart from cancer tracking systems, EHR systems and the first generation decision support such as rule based alert or and reminder systems. MATE actively evaluates diagnostic markers histo-pathological data and other patient related factors such as co-morbidities to generate patient specific recommendations for the clinical management. An advancedThe PROforma Tallis decision support technology enables MATE to rank the recommended options: for example - if the fitness of the patient is in question due to co-morbidity, MATE can recommend the next best option in terms ofwith supporting evidence. In principle, patient preferences could can also be factored in to the MATE decision model process and we are actively exploring the ways of supporting patient preferences as discussed in the last section under headingways of doing this in line with widely discussed needs for greater patient empowerment.

The All clinical recommendations made by MATE are presented to the user in the form of together with a summary of the rationale in the form of arguments, linked to the and supporting evidence, for transparency. The MATE knowledge base consisted ofhas been developed with reference to a comprehensive set of published national and international clinical practice guidelines, which enables MATE to provide give recommendations even in complex cases that are covered by these guidelines.

MATE also provides quantitative risk estimates based on published models as an adjunct to the clinical recommendations.

The user interface of MATE is illustrated in Fig 2. The detailed description of the knowledge base, technology and architecture is published elsewhere [20].

We used the following processes to understand and analyse the design issues and to feed back clinical experience into the MATE development lifecycle.

Evaluation phaseof concordance between MATE and MDT recommendations

Comment [v4]: Reviewer Clarity about how MATE was evaluated is needed: it is stated it was used prospectively (presumably in-situ?) but who operated it and could the team see the output? or was it used outside of the meeting? If used in situa and team could see output this casts the concordance exercise into doubt as the team would have seen the MATE recommendation. Also, the evaluation of data is not entirely clear: Were MATE recommendations compared to the MDT written recommendations, or were "MATE records amended to be in line with official MDM records" as stated in the evaluation phase section?

MATE was used in the background to prospectively record the proceedings of breast MDT meetings between April 2008 and July 2009 to gather 1,295 cases discussed in the MDMs during this period (each time a patient was discussed in the MDT meeting was counted as a separate encounter). The patient data and the MDT decisions were entered in MATE during the meeting by the first author. MATE recommendations were not shown to the MDT to avoid any confounding effect. After the meeting, the correctness of patient data and MDT recommendations entered in MATE were cross checked with the official paper MDT records by a separate data entry person, and, in case of any discrepancies, the patient data and MDT decisions entered in MATE record data were amended to be in line with the official MDT record. ~~An appropriate a~~Approval for an audit study was obtained from the Research and Development department of the hospital before starting the study~~was obtained before starting the study~~, and data-security measures such as encryption were put in place. ~~MATE allows us to capture both patient data and MDT decisions in a structured form. MATE~~ and these ~~records were cross-checked with the official MDM record sheets and, in case of any discrepancies, the MATE record was corrected to reflect the official MDM record.~~

One of the key ~~distinctive~~ features of MATE compared to a traditional electronic health record is the clinical decision support (CDS) element. MATE is able to *actively* evaluate patient data and to ~~*actively*~~ offer guideline-based recommendations in real time which are specific for each individual patient. We ~~used MATE to~~ compared MATE recommendations with *the* ~~*actual*~~ *MDT decisions*. ~~to that~~ those of ~~indicated by *guideline recommendations.*~~

The discordant cases (where MATE recommendations differed from those of MDT decisions) were further investigated by a panel who reviewed the patient's clinical notes. MATE also automatically flags patients who meet eligibility criteria for ongoing clinical trials.

Structured feedback from members of cancer networks in UK

The MATE development team was invited to conduct a workshop at the England Cancer Networks' Development Programme conference in March 2010. The conference

was attended by key members from all cancer networks, who are instrumental in governing and improving MDT conduct in their respective cancer networks. MATE was demonstrated in ~~the~~ a workshop and a questionnaire survey was conducted at the end of the presentation and discussion session. The MATE workshop at the Cancer Networks' Development Programme conference was attended by 54 people, of whom 48 completed the questionnaire. The roles of respondents were categorised as follows

Clinicians (Doctors & Nurses) = 13

Patients/survivors = 5

Service improvement managers = 18

Informaticians = 7

Others = 5

Respondents were asked to select from a choice of 5 categories (strongly agree, agree, neutral, disagree, strongly disagree) for five structured questions regarding usefulness of the system. They were also asked open ended questions to find any perceived barriers and their general comments.

Comment [v5]: Also, some methods appear in results - e.g. detail about content of questionnaire belongs in methods rather than results.

Results

Evaluation ~~phase~~phase results

~~A total of 1,295 breast cases were recorded on MATE between April 2008 and July 2009 (each time a patient was discussed in the MDT meeting was counted as a separate encounter)~~. The case mix of 1,295 breast cases included cancers and benign pathologies. Table 2 shows the overall distribution of cases recorded on the MATE system during the study ~~system~~. Metastatic, recurrent and non epithelial malignancies were excluded from the guideline concordance analysis as the guidelines and evidence-base for those subsets were not initially coded in MATE. In 239 cases of recurrent, metastatic or non-epithelial malignancies, MATE therefore provided data capture services but no decision support. The remaining 1056 cases were analysed for concordance between management recommendations made by MATE and the actual MDT decisions; ~~and~~ the level of concordance was encouragingly high (93.2 %; N = 984). When the 6.8 % discordant

cases were further analysed it was found that in 3.2% cases, the MDT ~~deviant~~ decisions which differed from MATE recommendations were corrected by the treating clinician in the results clinic.

MATE also identified 61% more patients who ~~were~~ were potentially eligible for recruitment into clinical trials than the MDT alone. Note that MATE only screens the patients as possibly eligible for the trials, based on the main eligibility criteria. All the information needed before recruiting the patient is often not available to the MDT. Certain tests specific for the trial (e.g. 2D Echo for ejection fraction) are done after MDT discussion and the results are not available at the MDM.

Structured Feedback results

The aim of the structured feed back was to estimate the acceptability of MATE and similar systems to the members of cancer networks, who are instrumental in governing and improving MDT conduct in the UK NHS system. For ~~the analysis~~simplicity we have combined "strongly agree" ~~or~~and "agree" responses ~~as~~ into an overall "agree" ~~category~~ rating and "neutral", "disagree" ~~or~~ and "strongly disagree" responses ~~as~~ into a an overall "disagree" ~~category~~rating. The "neutral" category was included in "disagree" to ensure a conservative interpretation.

There was a very high consensus ~~over~~ on the usefulness of clinical decision support in general, and MATE in particular, for cancer MDT meetings. Most respondents (95.8%) agreed that clinical decision support has a useful role in cancer MDMs. The majority of respondents found the services provided by MATE useful for the breast MDM (93.47) and potentially for other types of cancer MDMs (92.6%). The clinical decision support component and ability to automatically screen patients for ongoing clinical trials were seen as the two most valuable capabilities of MATE by the majority of respondents (84.5% and 81.2% of respondents respectively). Other capabilities of MATE, identified as valuable were patient data capture (70% of respondents), clinical audit services (67%), peer review support (58%) and education/training (45%). The majority of respondents (73.8%) were favourable to recommending MATE, if it were made available in their network.

The survey also identified important barriers to large-scale deployment of MATE. The main perceived obstacle to adoption was double data entry (50%) in situations where existing data capture systems are in place and it was suggested that MATE should be able to interface with existing data capture systems. Other barriers identified were costs and resources, clinical buy-in, scalability and the need for ~~scalable~~ appropriate knowledge maintenance mechanisms that can cope with the large volumes of clinical evidence.

Comment [v6]: Reviewer- Some jargon needs explaining e.g. 'scalable knowledge maintenance mechanisms' - what does this mean

Strategies for change and effects

The encouraging performance of MATE in this initial phase established the confidence of the breast team at RFH, and MATE was subsequently introduced as the standard breast MDM management tool. Introducing a new technology into as complex a setting as the cancer MDM was a challenging task and our implementation strategy was guided by the experiences of others reported in the literature.[21, 22]

The principles of the implementation strategy for MATE are summarised as follows.

- ~~*Building*~~ *Development around the existing clinical work-flow:* In order to ensure the clinical acceptability of MATE, a key design objective was to fit the system around the existing work-flow of the breast MDM and not the other way round.
- *Anticipating clinical needs and pragmatic constraints:* As well as obvious requirements such as access to detailed patient data, a number of other useful services were identified during the modelling phase (e.g. quick access to past MDT decisions).
- *Active involvement of users throughout audit, feedback and implementation:* As described in previous sections active participation of the users in the design process was encouraged through audit and feedback, and wider inputs from workshops and surveys.

Challenges and Next steps

We ~~would~~ wish to emphasize that the role of MATE or any similar IT system is purely supportive and the MDT meeting continues to be led by the clinical team. Advanced IT systems can only complement an effective and functional multidisciplinary team,[23] and cannot compensate for inherent weaknesses in team composition, organisation or operation. The preliminary audit results and the qualitative assessment data reported in this study, however encouraging, are at this point indicative of the potential benefits but not yet conclusive~~. They should be treated with caution~~ until further rigorous evaluations confirm the effectiveness and generalisability of MATE or similar services.

Generalisability:

It ~~is~~ has been reported that clinical decision support systems ~~are often at their best~~produce better results when the developing team is ~~involved in~~also responsible for the trial of the system. One review reported for example that the success rate for clinical decision support systems dropped from 74% to 28% when the systems were tested by independent teams.[24] The team involved in the development of MATE was also involved in testing and the deployment of the system so replication of our results on other sites is a key objective. It was for the same reason that the questionnaire survey from the user was not conducted at this stage and this is planned during the wider implementation phase. Demonstrating that MATE can confer significant benefits for other cancer MDTs is also a high priority. MATE has attracted the attention of the UK Department of Health's National Cancer Action Team and deployment of the system in other NHS trusts is being explored.

Effectiveness trials:

Definitive evidence of the value of complex (multifaceted) interventions such as MATE requires a multi-centre trial in which a cluster randomised design is likely to be the preferred methodology.[25] The trial should look into all important impacts of the

intervention including quantitative measures of cost, patient outcomes and process measures as well as qualitative measures.

Patient empowerment:

Patient involvement in decisions about their treatment is widely considered to be crucial to improving outcomes and many cancer patients wish to play a more active role in their care. The current structure of the cancer MDT meeting makes patient participation very difficult to achieve.[26] We are therefore exploring ways in which MATE could facilitate patient engagement, by extending access to certain of its functions by the patients~~, in~~. This could be achieved in a variety of settings, including consultations in results clinic and from the patient's home using the internet, allowing the patients to review their clinical history, ~~and~~ the MDT recommendations and ~~explanations~~ the reasons and justifying evidence for ~~the~~ those recommendations.

Ethics approval

Ethics approval was not required for the ~~submitted work~~study however for ~~the~~ a ~~subsequent~~ randomised controlled trial, which is ongoing, ethics approval was ~~taken from~~~~given~~obtained ~~by~~from the Moorfields & Whittington Research Ethics Committee.

Competing interest

All authors have completed the Unified Competing Interest form and declare that (1) None of the authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) [VP, DA, JF, MK] have following specified non-financial interests that may be relevant to the submitted work.

UCL(B) (a subsidiary of University College London) and ISIS innovation (a subsidiary of the University of Oxford) are actively seeking to commercialise aspects of this project through a spin-out company.

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Contributorship statement:
All authors have made substantial contributions as follow
VP, JF and MK: conception and design;
VP, DA, TD, AJ and MK: Conducting the pilot study
VP and DA: developing the ~~system~~MATE knowledge base and software;~~,~~ acquisition of data,
VP and MK: analysis and interpretation of data;
VP, DA, JF, MK: drafting the article;

All authors: revising ~~it~~ the manuscript critically for important intellectual content;
All authors: have given final approval of the version to be published.

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Table 1. Pragmatic challenges for cancer MDT meetings

1. Ensuring and documenting adherence with standards (e.g. evidence-based guidelines)
2. Identifying patients who are eligible for recruitment into clinical trials
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Figure 1. MATE in use at Royal Free breast MDT meeting.

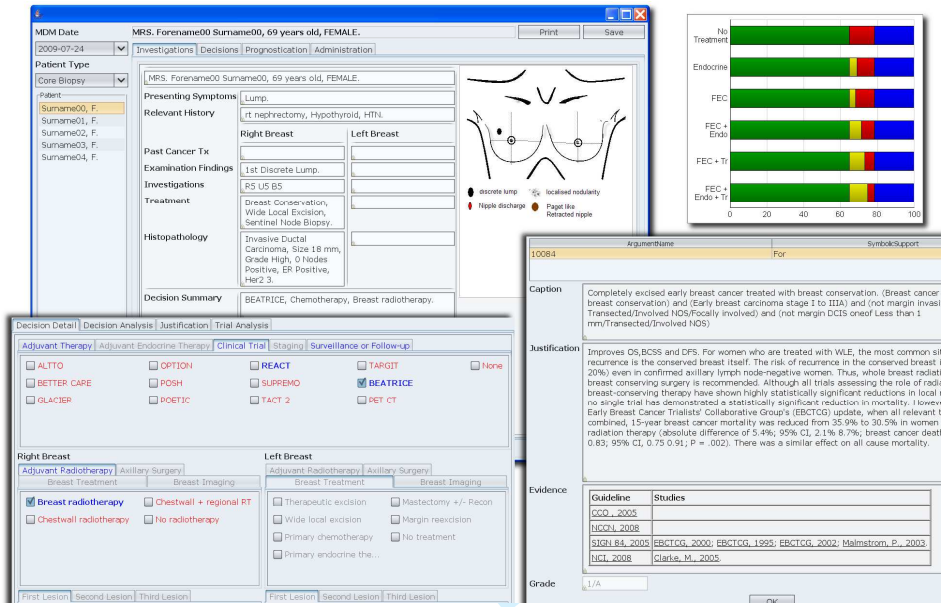

Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Pathology	Number
Benign breast disease	413
Operable breast cancer (in situ and invasive)	511
No final diagnosis reached (e.g. C1/C3/C4 on cytology or B1/B3/B4 on core biopsy) at the time of MDT meeting	132
Metastatic and or recurrent cancers	198
Other than breast epithelial malignancies	41
Total cases	1295

Table 2. Distribution of breast cases discussed at MDM according to type

Using computerised decision support to improve compliance of cancer multidisciplinary meetings with evidence-based guidance

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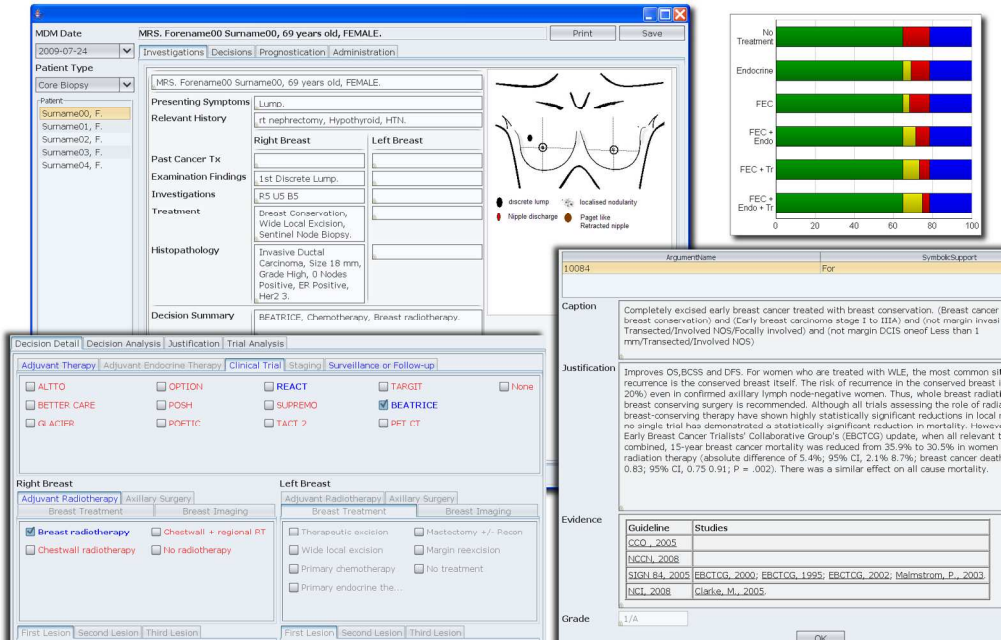
454x165mm (300 x 300 DPI)



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Using computerised decision support to improve compliance of cancer multidisciplinary meetings with evidence-based guidance

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Article summary

Article focus:

- How to improve the conduct of a cancer MDT and standardize decision-making in accordance with best evidence
- Development and implementation of a novel clinical decision support (CDS) platform for breast cancer MDT
- This study evaluates a) the concordance between the CDS suggestions and MDT recommendations; and b) the identification rate of potentially eligible patients for recruiting into the ongoing research trials, by the MDT and the CDS. A separate questionnaire survey was conducted at the national workshop at the Cancer Networks' Development Programme to get an estimate of acceptability of such MDT decision support systems by the cancer networks.

Key messages:

- An advanced CDS platform could significantly improve the conduct of cancer MDT meetings.
- Further robust evaluations are necessary.

Strengths and limitations:

- We share our experience of developing an advanced decision support system and implementing it in a complex clinical environment of cancer MDT which was subsequently adopted as a breast MDT meetings management tool.
-The results reported here, however encouraging, are at this point indicative of the potential benefits but not yet conclusive. They should be treated with caution until further rigorous evaluations confirm the effectiveness and generalisability of the CDS system.

Data sharing statement:

There is no additional data available.

Research checklist:

Appropriate research checklist could not be found.

Abstract:

Objectives: The cancer multidisciplinary team (MDT) meeting is regarded as the best platform to reduce unwarranted variation in cancer care through evidence-compliant management. However, MDT meetings are often overburdened with many different agendas, and hence struggle to achieve their full potential. We developed an interactive clinical decision support system called MATE (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), to facilitate explicit, evidence-based decision making in the breast MDT meetings ~~and to improve the overall conduct of the meeting~~.

Design: Audit study and a questionnaire survey.

Setting: Breast multidisciplinary unit in a large secondary care teaching hospital.

Participants: ~~The participants included a~~All members of the breast MDT at the Royal Free Hospital, London, were consulted during the process of MATE development and implementation. ~~-~~The emphasis was on ~~active user participation through audit, feedback and response,~~ acknowledging the clinical needs and practical constraints of the MDT and fitting the system around the team's work-flow rather than the other way around. Delegates, who attended MATE workshop at the England Cancer Networks' Development Programme conference in March 2010, participated in the questionnaire survey.

Outcome measures: The measures included evidence compliant care; measured by adherence to clinical practice guidelines (CPGs) and promoting research; measured by the patient identification rate for ongoing clinical trials.

Results: MATE identified 61% more patients who were potentially eligible for recruitment into clinical trials than the MDT and MATE recommendations demonstrated better concordance with CPG than MDT recommendations (97% of MATE vs 93.2 % of MDT; N = 984). MATE is in routine use in breast MDT meetings at the Royal Free hospital, London and wider evaluations are being considered.

Conclusions: Sophisticated decision support systems can enhance the conduct of MDT meetings in a way that is acceptable to and valued by the clinical team. Further rigorous evaluations are required to examine cost-effectiveness and measure the impact on patient outcomes. The decision support technology used in MATE is generic and if found useful can be applied across medicine.

Problem statement

Unwarranted practice variation across different medical domains has unfortunately become a pervasive finding in health service research and breast cancer care is no exception.[1] A recently published study reported significant differences in breast cancer survival across hospitals in the same geographical region in England.[2] The reasons for practice variation are multifactorial and standardisation of care has been attempted by the introduction of Regional Cancer Networks in England and the adoption of the Multi Disciplinary Team (MDT) model to promote maximal adoption of evidence-based practice. The MDT model is increasingly being adopted in other non-cancer medical domains such as stroke, cardiovascular diseases and diabetes.

Many benefits of MDTs have been claimed, but few have been backed by strong evidence.[3,4] However, despite a significant lack of prospective evidence, MDTs are well accepted in clinical practice; they are regarded as a major advance in management of cancer patients and their use appears to be increasing.[5] As many health care systems have already committed to and invested in the MDT model, further reductions in unwarranted variation are likely to be best achieved by improving their conduct and standardizing their decision making processes.[6] Data collected by the UK national cancer peer review programme from over 1000 teams across six cancer types in England indicates that there is significant room for improvement in the conduct of MDT meetings and shows considerable variability in the performance of MDTs.[7] A recent national survey of more than 2000 members of cancer multidisciplinary teams, demonstrated agreement on the range of criteria necessary for effective MDT working.[3] A review of the literature by the authors identified many pragmatic challenges and shortcomings in the current conduct of cancer MDT meetings summarised in Table 1.[8]

Context

The Royal Free Hospital NHS Trust (RFH) serves a population of 2.6 million within the North London Cancer Network (NLCN) catchment area. The number of new patients (both benign and cancer) seen as outpatients by the breast unit in 2009-10 was 2,944. The Breast Cancer Multidisciplinary team at RFH was established in 2005, in line with the recommendations of the NHS Cancer Plan. The MDT uses a set of NLCN-approved clinical guidelines and a standardized minimum data set.

MDT meetings (MDM) are held every week in a conventional conference format. The core members of a breast MDT include breast surgeons, radiologists, pathologists, medical and clinical oncologists, plastic surgeons and breast clinical nurse specilaists. A typical breast MDM discusses an average of 30 to 40 patients at various stages in their care pathways every week to decide further courses of action in their management.

Prior to the introduction of our computer-based service into the MDT meetings, an entirely paper based record system was used to provide case summaries and to document the MDT's discussion and decisions. These records contained free (unstructured) text rather than coded and structured data. The tradeoffs between structured (computer interpretable) and unstructured electronic health records (EHR~~s~~) are well known.[9] Recording MDT discussions in an unstructured form such as free text clinical notes, scanned documents, pdfs etc, hinders the process of accurate measurement of MDT performance as computer based data analysis and auditing tools cannot be used on unstructured data.

There are many commercially available information and communication systems which can assist in the preparation, presentation and documentation of cases at the MDT meetings such as EHR systems. However the objectives of our MDT service improvement exercise was to go beyond improvements in data management by providing active support for evidence-based decision making, improving recruitment into clinical trials and supporting prospective audit.[10]

Measures of improvement

Evidence compliant care: Adherence with clinical practice guidelines

With the increasing recognition of shortcomings in healthcare systems, there is a significant cultural and professional shift towards using evidence-based guidance. Evidence-based standards of care, such as published practice guidelines and technology assessment reports developed by authoritative organisations, provide an objective standard against which to assess MDT decisions. There is growing evidence that use of evidence-based guidelines can improve patient outcomes,[11-13] and MDT meetings provide the best opportunity to actively promote an *appropriate* and *judicious* use of the guidelines at the point of care.

Promoting research: Identification of patients eligible for ongoing research trials

It is widely accepted that recruiting patients into clinical trials is an effective strategy for ensuring that cancer patients get the best care as well as providing important information about the efficacy of treatments. However, the literature continues to report low rates of accrual to cancer clinical trials[14] and many organisations at national and international levels are investigating strategies for improving accrual rates. Cancer MDT meetings offer a major opportunity for identifying patients who are eligible for participation in clinical trials.[15]

Methods

In order to assess the performance of the breast MDT on the above mentioned measures we developed a computerised decision support system, **MATE** (**M**ultidisciplinary meeting **A**ssistant and **T**reatment s**E**lector), that captures patient data, identifies eligible patients for clinical trials and suggests evidence-based treatment recommendations. MATE also captures MDT decisions and hence can automatically compare them with guideline recommendations.

System development

We followed a systematic, stepwise approach throughout the system development lifecycle. Requirements for MATE were identified through a systematic review of the

literature[16] and by working closely with members of the breast MDT at RFH. We adopted the Common KADS methodology to develop a comprehensive process and knowledge model for breast cancer MDT meetings.[17] A controlled vocabulary from the National Cancer Institute thesaurus [18] was used to facilitate data standardisation. The evidence sources reviewed included Clinical Practice Guidelines, Systematic Reviews and Meta-analyses and reports of Randomised Controlled trials. Along with the guideline recommendations, the eligibility criteria of ongoing clinical trials in breast cancer that were open for recruitment at our institution were also coded into the system.

PRO*forma*,[19] an established decision modelling language for modelling clinical decisions and care pathways, was used to formalise decisions and supporting evidencein MATE. The PRO*forma* language and application development software Tallis used in this project were originally developed at Cancer Research UK. Tallis was used to implement a range of decision support and other services[1] as determined by the requirements development process outlined above, and is used to update recommendations and other components of the PRO*forma* knowledge base when new guidance is published. Tallis is being developed jointly by Oxford University and the Royal Free development team.

System description

MATE functionality can be categorised under two broad headings: 1. Structured data capture, presentation and audit 2. Advanced evidence-based decision support

Data capture: MATE allows users to capture detailed structured clinical data including, demographics, co morbidities, test results, clinical findings, imaging, pathology and treatment related data. The data are entered into the system either before (preparation phase) or during the MDT meetings (presentation phase). In the preparation phase the data are entered by a clinician, who is responsible for the preparation of the meeting. Data entry is flexible, quick and secure and it was found to reduce preparation time. If

[1] http://mate.cossac.org/

some of the test results such as pathology reports are not available before the MDT meeting, they can easily be entered in MATE during the meeting by a clinician without delaying the proceedings. MATE also provides patient summaries automatically and prospective audit facilities.

Advanced evidence-based decision support module: is the key component of MATE which sets it apart from cancer tracking systems, EHR systems and the first generation decision support such as rule based alert and reminder systems. MATE actively evaluates diagnostic markers histo-pathological data and other patient related factors such as co-morbidities to generate patient specific recommendations for clinical management. The Tallis decision support technology enables MATE to rank the recommended options: for example - if the fitness of the patient is in question due to co-morbidity, MATE can recommend the next best option with supporting evidence. In principle, patient preferences can also be factored into the MATE decision process and we are actively exploring ways of doing this in line with widely discussed needs for greater patient empowerment.

All clinical recommendations made by MATE are presented to the user together with a summary of the rationale in the form of arguments and supporting evidence. The MATE knowledge base has been developed with reference to a comprehensive set of published national and international clinical practice guidelines, which enables MATE to give recommendations even in complex cases that are covered by these guidelines.

MATE also provides quantitative risk estimates based on published models as an adjunct to the clinical recommendations.

The user interface of MATE is illustrated in Fig 2. The detailed description of the knowledge base, technology and architecture is published elsewhere [20].

Evaluation of concordance between MATE and MDT recommendations

MATE was used in the background to prospectively record the proceedings of breast MDT meetings between April 2008 and July 2009 to gather 1,295 cases discussed in the MDMs during this period (each time a patient was discussed in the MDT meeting

was counted as a separate encounter). The patient data and the MDT decisions were entered in MATE during the meeting by the first author. MATE recommendations were not shown to the MDT to avoid any confounding effect. After the meeting, the correctness of patient data and MDT recommendations entered in MATE were cross checked with the official paper MDT records by a ~~separate data entry person~~research associate from the research team and, in case of any discrepancies, the patient data and MDT decisions entered in MATE record data were amended to be in line with the official MDT record. Approval for an audit study was obtained from the Research and Development department of the hospital before starting the study, and data-security measures such as encryption were put in place.

One of the key features of MATE compared to a traditional electronic health record is the clinical decision support (CDS) element. MATE is able to *actively* evaluate patient data and to offer guideline-based recommendations in real time which are specific for each individual patient. We compared MATE recommendations with *the MDT decisions*. The discordant cases (where MATE recommendations differed from those of MDT decisions) were further investigated by a panel who reviewed the patient's clinical notes. MATE also automatically flags patients who meet eligibility criteria for ongoing clinical trials.

Structured feedback from members of cancer networks in UK

The MATE development team was invited to conduct a workshop at the England Cancer Networks' Development Programme conference in March 2010. The conference was attended by key members from all cancer networks, who are instrumental in governing and improving MDT conduct in their respective cancer networks. MATE was demonstrated in a workshop and a questionnaire survey was conducted at the end of the presentation and discussion session. The aim of the structured feed back was to gather the views of the members of cancer networks about the usefulness of clinical decision support systems in general and MATE in particular, in the context of cancers MDMS. ~~The MATE workshop at the Cancer Networks' Development Programme conference was~~

~~attended by 54 people, of whom 48 completed the questionnaire. The roles of respondents were categorised as follows~~

~~Clinicians (Doctors & Nurses) = 13~~

~~Patients/survivors = 5~~

~~Service improvement managers = 18~~

~~Informaticians = 7~~

~~Others = 5~~

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Respondents were asked to select from a choice of 5 categories (strongly agree, agree, neutral, disagree, strongly disagree) for five structured questions regarding usefulness of the system. They were also asked open ended questions to find any perceived barriers and their general comments. The questionnaire is summarised in For simplicity we have combined "strongly agree" and "agree" responses into an overall "agree" rating and "neutral", "disagree" and "strongly disagree" responses into a an overall "disagree" rating. The "neutral" category was included in "disagree" to ensure a conservative interpretation.

Results

Evaluation phase results

The case mix of 1,295 breast cases included cancers and benign pathologies. Table 2 shows the overall distribution of cases recorded on the MATE system during the study. Metastatic, recurrent and non epithelial malignancies were excluded from the guideline concordance analysis as the guidelines and evidence-base for those subsets were not initially coded in MATE. In 239 cases of recurrent, metastatic or non-epithelial malignancies, MATE therefore provided data capture services but no decision support. The remaining 1056 cases were analysed for concordance between management recommendations made by MATE and the actual MDT decisions; the level of concordance was encouragingly high (93.2 %; N = 984). When the 6.8 % discordant cases were further analysed it was found that in 3.2% cases, the MDT decisions which differed from MATE recommendations were corrected by the treating clinician in the

results clinic.

MATE also identified 61% more patients who were potentially eligible for recruitment into clinical trials than the MDT alone. Note that MATE only screens the patients as possibly eligible for the trials, based on the main eligibility criteria. All the information needed before recruiting the patient is often not available to the MDT. Certain tests specific for the trial (e.g. 2D Echo for ejection fraction) are done after MDT discussion and the results are not available at the MDM.

Structured Feedback results

The MATE workshop at the Cancer Networks' Development Programme conference was attended by 54 people, of whom 48 completed the questionnaire. The roles of respondents were categorised as follows

Clinicians (Doctors & Nurses) = 13

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~~The aim of the structured feed back was to estimate the acceptability of MATE and similar systems to the members of cancer networks, who are instrumental in governing and improving MDT conduct in the UK NHS system. For simplicity we have combined "strongly agree" and "agree" responses into an overall "agree" rating and "neutral", "disagree" and "strongly disagree" responses into a an overall "disagree" rating. The "neutral" category was included in "disagree" to ensure a conservative interpretation.~~

There was a very high consensus on the usefulness of clinical decision support in general, and MATE in particular, for cancer MDT meetings. Most respondents (95.8%) agreed that clinical decision support has a useful role in cancer MDMs. The majority of respondents found the services provided by MATE useful for the breast MDM (93.47) and potentially for other types of cancer MDMs (92.6%). The clinical decision support component and ability to automatically screen patients for ongoing clinical trials were

seen as the two most valuable capabilities of MATE by the majority of respondents (84.5% and 81.2% of respondents respectively). Other capabilities of MATE, identified as valuable were patient data capture (70% of respondents), clinical audit services (67%), peer review support (58%) and education/training (45%). The majority of respondents (73.8%) were favourable to recommending MATE, if it were made available in their network.

The survey also identified important barriers to large-scale deployment of MATE. The main perceived obstacle to adoption was double data entry (50%) in situations where existing data capture systems are in place and it was suggested that MATE should be able to interface with existing data capture systems. Other barriers identified were costs and resources, clinical buy-in, scalability and the need for appropriate knowledge maintenance mechanisms that can cope with the large volumes of clinical evidence.

~~**Strategies for change and effects**~~

~~The encouraging performance of MATE in this initial phase established the confidence of the breast team at RFH, and MATE was subsequently introduced as the standard breast MDM management tool. Introducing a new technology into as complex a setting as the cancer MDM was a challenging task and our implementation strategy was guided by the experiences of others reported in the literature.[21, 22]~~

~~The principles of the implementation strategy for MATE are summarised as follows.~~

- ~~*Development around the existing clinical work-flow:* In order to ensure the clinical acceptability of MATE, a key design objective was to fit the system around the existing work-flow of the breast MDM and not the other way round.~~
- ~~*Anticipating clinical needs and pragmatic constraints:* As well as obvious requirements such as access to detailed patient data, a number of other useful services were identified during the modelling phase (e.g. quick access to past MDT decisions).~~

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- ~~*Active involvement of users throughout audit, feedback and implementation:* As described in previous sections active participation of the users in the design process was encouraged through audit and feedback, and wider inputs from workshops and surveys.~~

Challenges and Next steps

We wish to emphasize that the role of MATE or any similar IT system is purely supportive and the MDT meeting continues to be led by the clinical team. Advanced IT systems can only complement an effective and functional multidisciplinary team,[~~23~~21] and cannot compensate for inherent weaknesses in team composition, organisation or operation. The preliminary audit results and the qualitative assessment data reported in this study, however encouraging, are at this point indicative of the potential benefits but not yet conclusive until further rigorous evaluations confirm the effectiveness and generalisability of MATE or similar services.

Generalisability:

It has been reported that clinical decision support systems produce better results when the developing team is also responsible for the trial of the system. One review reported for example that the success rate for clinical decision support systems dropped from 74% to 28% when the systems were tested by independent teams.[~~24~~22] The team involved in the development of MATE was also involved in testing and the deployment of the system so replication of our results on other sites is a key objective. It was for the same reason that the questionnaire survey from the user was not conducted at this stage and this is planned during the wider implementation phase. Demonstrating that MATE can confer significant benefits for other cancer MDTs is also a high priority. MATE has attracted the attention of the UK Department of Health's National Cancer Action Team and deployment of the system in other NHS trusts is being explored.

Effectiveness trials:

Definitive evidence of the value of complex (multifaceted) interventions such as MATE requires a multi-centre trial in which a cluster randomised design is likely to be the preferred methodology.[~~25~~23] The trial should look into all important impacts of the intervention including quantitative measures of cost, patient outcomes and process measures as well as qualitative measures.

Patient empowerment:

Patient involvement in decisions about their treatment is widely considered to be crucial to improving outcomes and many cancer patients wish to play a more active role in their care. The current structure of the cancer MDT meeting makes patient participation very difficult to achieve.[~~26~~24] We are therefore exploring ways in which MATE could facilitate patient engagement, by extending access to certain of its functions by the patients. This could be achieved in a variety of settings, including consultations in results clinic and from the patient's home using the internet, allowing the patients to review their clinical history, the MDT recommendations and the reasons and justifying evidence for those recommendations.

Ethics approval

Ethics approval was not required for the study however for a randomised controlled trial, which is ongoing, ethics approval was obtained from the Moorfields & Whittington Research Ethics Committee.

Competing interest

All authors have completed the Unified Competing Interest form and declare that (1) None of the authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) [VP, DA, JF, MK] have following specified non-financial interests that may be relevant to the submitted work.
UCL(B) (a subsidiary of University College London) and ISIS innovation (a subsidiary of the University of Oxford) are actively seeking to commercialise aspects of this project through a spin-out company.

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Contributorship statement:
All authors have made substantial contributions as follow
VP, JF and MK: conception and design;
VP, DA, TD, AJ and MK: Conducting the pilot study
VP and DA: developing the MATE knowledge base and software; acquisition of data,
VP and MK: analysis and interpretation of data;
VP, DA, JF, MK: drafting the article;
All authors: revising the manuscript critically for important intellectual content;
All authors: have given final approval of the version to be published.

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6. Achieving the right balance of educational and care delivery objectives of this forum
7. Establishing reliable interfaces with primary care to ensure continuity of care

Figure 1. MATE in use at Royal Free breast MDT meeting.

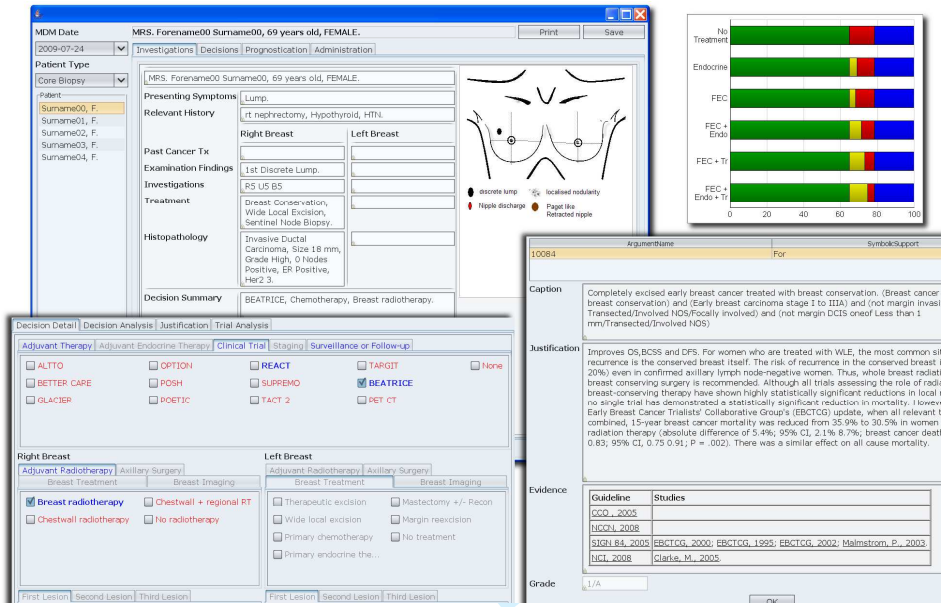

Figure 2. Composite screen-shot showing the user interface and some of the functionalities of MATE; Upper left: the summary screen for the patient. Upper right: one of the many prognostication tools available, Lower left: decision panel where system recommendations and eligible clinical trials are highlighted in blue. Lower right: the evidential justification for each recommended option.

Pathology	Number
Benign breast disease	413
Operable breast cancer (in situ and invasive)	511
No final diagnosis reached (e.g. C1/C3/C4 on cytology or B1/B3/B4 on core biopsy) at the time of MDT meeting	132
Metastatic and or recurrent cancers	198
Other than breast epithelial malignancies	41
Total cases	1295

Table 2. Distribution of breast cases discussed at MDM according to type