The effects of cancer clinical decision support systems on patient-reported outcomes: A systematic review

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Abstract

**Background:** The availability and implementation of high-quality decision-making support are integral to ensuring the delivery of quality cancer care and subsequently achieving positive patient outcomes and experiences. Decision Support Systems (DSS) are increasingly used to support decision-making in clinical practice. However, it is not known beyond supporting the decision-making process whether DSS are indeed effective in improving outcomes for people affected by cancer. The purpose of this review was to identify and synthesize the available literature regarding the effects of DSS on patient-reported outcomes in cancer, both during and after cancer treatment.

**Methods:** We conducted a systematic search of four databases for empirical literature published between 2000 and July 2021, in the English language, that reported an evaluation of patient-reported outcomes. Key information was extracted from each article including study design, type of cancer, intervention elements, type of DSS intervention, measures, and key outcomes. We appraised study quality using the Mixed Methods Appraisal Tool (MMAT).

**Results:** We included 14 studies, which we categorized as symptom assessment interventions or interactive educational interventions. Studies described a range of health-related and process-related patient-reported outcomes, as well as decisional complexities. Findings were mixed regarding the effectiveness of clinical DSS interventions in improving total symptom distress and severity, whereas the majority were effective in reducing mean scores for worst and usual pain. Interventions were not effective in improving other health-related patient-reported outcomes including quality of life, global distress, depression, or self-efficacy and there were mixed effects for reducing decisional conflict. Regarding process-related patient-reported outcomes, there was moderate to high patient adherence to the intervention as well as generally high satisfaction and acceptability. However, there was minimal evidence for the effect of clinical DSS interventions in clinician adherence to intervention recommendations.

**Conclusions:** Inconsistencies in reporting of interventions may be a contributing factor to heterogeneous effects of clinical DSS regarding a broad range of patient-reported outcomes. There is a need to develop and implement evidence-based reporting guidelines to improve the reliability and validity of reporting clinical DSS interventions and enhance their timely translation into practice.

**Systematic review registration:** PROSPERO (CRD42020190977)

1. Introduction

Amid the rising cancer incidence across the world, advancements in cancer treatments and technologies have increased the complexity of decision-making in clinical care [1, 2]. Treatment decisions are often highly complex when a patient’s outcomes are uncertain, resulting in a variety and choice in treatment options, which may also be valued differently by clinicians and patients [3, 4]. It is essential to strive for efficient, effective, and high-quality cancer treatment and care to achieve optimal patient and health service outcomes, balanced with ever-rising treatment costs, finite resources, and patient values [1, 2]. However, succeeding in these objectives requires the right decisions to be made at the right time.

The availability and implementation of high-quality decision-making support is integral to ensuring the delivery of quality cancer care achieves positive patient experiences and outcomes [5]. Shared decision-making (SDM) is an approach where both clinicians and patients are involved in an informed decision-making process. Clinicians and patients should both be guided by the best available evidence, with the opportunity to consider various options and how they align with the patients’ values [6, 7]. Decision Support Systems (DSS), as interactive technologies, should strive to support and achieve informed shared decision-making between clinicians and patients. DSS uses patient-specific information and assessments to make tailored decisions, which can then be acted upon, often by healthcare providers. Such decisions span the continuum of cancer care across diagnosis, treatment, follow up, and monitoring [8–10].

Over the past two decades, DSS have rapidly evolved with a diversity of applications and functions within the health and medical care setting [8, 11]. For example, DSS are increasingly integrated into electronic health records [12], used to promote clinician adherence to clinical guidelines [11], manage medication prescribing [13], improve clinician workflow [8], and estimate costs of care delivery [14].

In the context of cancer care, previous systematic reviews investigating the implementation and effectiveness of DSS have synthesized findings regarding electronic chemotherapy orders, guideline adherence, staging and investigations and treatment decisions [15–17]. Benefits described include saving time and money, a better understanding of clinical needs, better use of health system resources, and reduced variation in the quality of care [16, 18]. As such, DSS have the potential to drive evidence-based standardization of cancer care and thus to optimize patient outcomes [15]. However, beyond supporting decision-making processes, it is not known whether DSS are indeed effective in improving outcomes for people affected by cancer [15, 19–21].

To address this gap, we aimed to identify and synthesize the available literature regarding the effects of clinical DSS on patient-reported outcomes. Specifically, we were interested in the use of clinical DSS by patients and clinicians to improve clinical patient-reported outcomes both during and after cancer treatment [8].

2. Methods

The protocol for this review was registered with PROSPERO (CRD42020190977). The research questions guiding this review were: 1) What patient-reported outcomes are measured using clinical DSS in the cancer context? and 2) What is the effect of clinical DSS on patient-reported outcomes for people with cancer?

For this review, we defined DSS as:
“Decision Support Systems use...individual patient characteristics to generate patient-specific evidence-based assessments or recommendations. These systems require computable biomedical knowledge, person-specific data, and a reasoning or inferencing mechanism that combines knowledge and data to generate and present information to clinicians as care is being delivered.”[15](p331).

2.1 Search strategy

We used a combination of keywords and MeSH terms, along with Boolean operators to specify essential elements of the search strategy including the population (cancer and oncology); intervention (Clinical Decision Support System and decision-making); and outcomes (patient-reported outcome measures or treatment outcomes). The complete search strategy can be viewed in Supplementary Table 1. We searched four databases (PubMed, CINAHL, EMBASE and Web of Science) and also hand-searched the reference lists of included articles. Database searches were completed in July 2021.

2.2 Eligibility criteria

The target population for this review were patients with any type of cancer; unrestricted by age or sex, and within any setting (e.g. hospital, home, community). We included patients who were diagnosed with cancer, either on active treatment, after treatment, or receiving palliative care. We included articles if they reported on the effectiveness of clinical DSS (as defined above) to enhance treatment and/or supportive care decisions and subsequently improve patient-reported outcomes. We included articles with any study design (except literature reviews and protocols), excluding grey literature, published up until July 2021, and in the English language.

We included articles if they reported on changes in clinical patient-reported outcomes, either objectively or subjectively, as a result of implementing clinical treatment or care-related recommendations derived through the use of clinical DSS. Interventions were included if patient data and/or patient-reported outcomes were entered into the DSS by either the patient or a clinician (that is, patient-facing or patient and clinician-facing DSS). The primary outcome of interest was any health-related patient-reported outcome (e.g. symptom burden, quality of life, depression or anxiety). We were also interested in patient-reported process outcomes related to the use of the clinical DSS (e.g. satisfaction, acceptability and patient adherence to clinical DSS recommendations), including decisional complexities (e.g. decisional conflict or regret). We also assessed clinician decisions that may influence patient-reported outcomes, for example, clinician adherence to clinical DSS recommendations.

2.3 Study selection

We undertook the study selection process using Covidence systematic review management software [22]. Upon importing references to Covidence, we removed any duplicate citations. At least two reviewers (K.A., N.B., E.R., E.P) screened each title and abstract for inclusion based on the predefined eligibility criteria with discrepancies resolved by a third reviewer (K.A., N.B., E.P). Two reviewers (E.P, N.B., K.A.) independently assessed full-text articles by for eligibility, again, with consensus reached through discussion with a third reviewer (K.A., N.B., E.P). We supplemented our database search by hand-searching reference lists of included articles. The PRISMA flow diagram depicting the study selection process is presented in Fig. 1.

2.4 Quality assessment

We used the Mixed Methods Assessment Tool (MMAT) to assess the reporting quality of included articles. MMAT is an appraisal tool designed specifically for undertaking systematic reviews that contain multiple and diverse study designs [23, 24]. In line with the MMAT instructions, we did not exclude articles based on the determined quality of articles [23]. Rather, we used it as a means to understand and assess various aspects of articles contributing to the methodological rigour of the research [25].

2.5 Data Extraction and synthesis

Data extraction was undertaken by one reviewer (E.P) using Extraction 2.0 within Covidence through the development of a custom designed extraction template. Key information from each article was summarised including lead author; year of publication; study location; study aim; type of cancer; study design; participants; intervention elements; type of DSS intervention; measures; and key outcomes (refer to Table 1). Extracted data were cross-checked for accuracy and validity by a second reviewer (N.B.).
<table>
<thead>
<tr>
<th>Article</th>
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</thead>
<tbody>
<tr>
<td>Berry et al;</td>
<td>USA</td>
<td>To compare usual patient education plus the internet-based, Personal patient Profile-Prostate, versus usual care alone on conflict associated with decision making, time to treatment and treatment choice.</td>
<td>Prostate</td>
<td>RCT</td>
<td>N = 494 eligible men (N = 266 intervention, N = 228 control) Intervention - mean age 62 (40-84y) Control - mean age 63 (45-86y)</td>
<td>Provision of basic and customized education/information. Education and communication coaching/support.</td>
<td>Interactive Educational Intervention</td>
<td>Decisional conflict Intervention acceptability</td>
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<td>2013 [26]</td>
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<tr>
<td>Berry et al;</td>
<td>USA</td>
<td>To evaluate the efficacy of the web-based Personal patient Profile-Prostate versus usual care with regard to decisional conflict, decisional regret and satisfaction.</td>
<td>Prostate</td>
<td>RCT</td>
<td>N = 392 men (N = 198 Intervention, N = 194 usual care)</td>
<td>Provision of basic and customized education/information. Education and communication coaching/support. Printed or online teaching materials/reports.</td>
<td>Interactive Educational Intervention</td>
<td>Decisional conflict</td>
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<td>2018 [27]</td>
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CI – Confidence Interval; DSS – Decision Support System; GSI – Global Symptom Index; MSAS-SF – Memorial Symptom Assessment – Short Form; QoL – Q Randomized Controlled Trial; SD – Standard Deviation; SE – Standard Error
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<tr>
<td>Cleeland et al; 2011</td>
<td>USA</td>
<td>To establish if patients in the intervention group are less likely to have symptoms that meet or exceed a predetermined severity threshold over time than patients in the control group. To identify if there are group differences in reported symptom interference, acceptability of the intervention and acceptability with symptom control</td>
<td>Lung Cancer/Metastases</td>
<td>RCT</td>
<td>N = 100 – 50 per arm Intervention (N = 38 completed - mean age 59.2y, SD 13.6) Control (N = 41 completed - mean age 60.9y, SD 11.8)</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS.</td>
<td>Symptom Assessment Intervention</td>
<td>Multiple symptom burden Patient satisfaction/interver acceptability</td>
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<tr>
<td>Du Pen et al; 2000 [29] USA</td>
<td>To test the application of a cancer pain algorithm with community oncologists and nurses by comparing “algorithm-trained” and “non-algorithm-trained” practitioners.</td>
<td>Various</td>
<td>RCT</td>
<td>N = 20 oncologists and N = 38 oncology nurses N = 118 recruited. Outcome data on N = 105. N = 54 in intervention group (mean age 61 years, SD 1.5); N = 51 in control (mean age 61 years, SD 1.4)</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS.</td>
<td>Symptom Assessment Intervention</td>
<td>Pain Patient adherence Clinician adherence</td>
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<tr>
<td>Fallon et al; 2018 [30]</td>
<td>UK</td>
<td>To compare the effect of adding a clinician-delivered beside pain assessment and management tool to usual care versus usual care alone on pain outcomes.</td>
<td>Various</td>
<td>RCT</td>
<td>N = 19 centers (N = 10 in intervention and N = 9 in control) N = 1921 patients enrolled - N = 993 in intervention and N = 928 in control. Across all patients - mean age was 59.8 years, SD 13.3</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS.</td>
<td>Symptom Assessment Intervention</td>
<td>Pain Global distress Patient/clinician satisfaction Clinician adherence</td>
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<tr>
<td>Gustafson et al; 2013</td>
<td>USA</td>
<td>To examine the effectiveness of an online support system versus the internet in relieving physical symptom distress in patients with non-small cell lung cancer.</td>
<td>Lung Cancer</td>
<td>RCT</td>
<td>N = 285 caregiver-patient dyads which dropped to 246 after randomization</td>
<td>Provision of basic and customized education/information. Education and communication coaching/support. Printed or online teaching materials/reports.</td>
<td>Interactive Educational Intervention</td>
<td>Multiple symptom burden Survival</td>
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<td>Kearney et al; 2009</td>
<td>UK</td>
<td>To explore the effect of an advanced symptom management system on the incidence, severity and distress of six chemotherapy-related symptoms in patients with lung, breast or colorectal cancer</td>
<td>Breast, lung or colorectal cancer</td>
<td>RCT</td>
<td>N = 112 (N = 56 in each arm). Mean age 56 years, SD 10.5</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS.</td>
<td>Symptom Assessment Intervention</td>
<td>Multiple symptom burden</td>
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<td>McCann et al; 2009</td>
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<td>To evaluate the impact of a mobile phone-based, remote monitoring system on chemotherapy related toxicity in patients with lung, breast or colorectal cancer.</td>
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<td>Patient satisfaction/percept</td>
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<td>Lohre et al; 2020</td>
<td>Norway</td>
<td>To investigate whether there would be significant improvement in pain control if patients systematically registered patient-reported outcome measures and if physicians applied evidence-based decision support</td>
<td>Various</td>
<td>Non-randomised experimental study</td>
<td>N = 52 (N = 41 discharged alive). Mean age 67 (44-91y)</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician.</td>
<td>Symptom Assessment Intervention</td>
<td>Pain</td>
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<td>Clinician input/response to information provided by patients through DSS.</td>
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<td>Clinician adherence</td>
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<tr>
<td>Mooney et al; 2014</td>
<td>USA</td>
<td>To explore whether timely provider notification of poorly controlled symptoms would prompt oncology providers to communicate with patients and intensify treatment of unrelieved symptoms and lead to improved symptom outcomes.</td>
<td>Various</td>
<td>RCT</td>
<td>N = 250. Intervention N = 129; Control N = 121</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS.</td>
<td>Symptom Assessment Intervention</td>
<td>Multiple symptom burden Patient satisfaction/intervention acceptability Patient adherence</td>
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<tr>
<td>Mooney et al; 2017[36]</td>
<td>USA</td>
<td>To test whether an automated symptom management system can reduce the severity of chemotherapy-related symptoms.</td>
<td>Various</td>
<td>RCT</td>
<td>N = 358 patients. N = 180 in intervention (mean 56.8 years (10.5 SD)) and N = 178 in control (usual care) (mean 54.8 years (11.4 SD)).</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS. Provision of customized education/information. Education and communication coaching/support.</td>
<td>Symptom Assessment Intervention</td>
<td>Multiple symptom burden Patient adherence</td>
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<td>Raj et al;</td>
<td>Norway</td>
<td>To identify if there are improvements in pain control as a result of implementing the COMBAT system.</td>
<td>Various</td>
<td>Non-randomised experimental study</td>
<td>N = 247 (N = 103 pre-intervention; N = 151 intervention period) Analysis - Before intervention group (N = 80, mean age 58.6, SD 13.3)); After intervention group (N = 134, mean age 61, SD 12.2).</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician.</td>
<td>Symptom Assessment Intervention</td>
<td>Pain, Clinician adherence</td>
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<td>Ruland et al; 2013 [38]</td>
<td>Norway</td>
<td>To evaluate the effects of an intervention in improving symptom distress, depression, self-efficacy and quality of life compared to the control.</td>
<td>Breast or prostate cancer</td>
<td>RCT</td>
<td>N = 162 in intervention group (mean age 56.9 years, SD 10.7); N = 163 in control group (mean age 56.4 years, SD 11.5).</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS. Provision of basic and customized education/information. Education and communication coaching/support.</td>
<td>Interactive Educational Intervention</td>
<td>Multiple symptom burden Depression Self-efficacy Health-related QoL</td>
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<tr>
<td>Sikorskii et al; 2007 [39]</td>
<td>USA</td>
<td>To assess whether nurse assisted symptom management compared to automated telephone symptom management results in lower symptom severity.</td>
<td>Various</td>
<td>RCT</td>
<td>N = 437 completed the baseline interview and were randomized. N = 219 to intervention group (mean age 57.1, SD 12.0) and N = 218 to control group (57.3, SD 11.8).</td>
<td>System to monitor and/or report symptoms inputted by patient and/or clinician. Clinician input/response to information provided by patients through DSS. Provision of customized education/information.</td>
<td>Symptom Assessment Intervention</td>
<td>Multiple symptom burden Patient adherence</td>
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We assessed the effects of interventions and grouped the outcomes into categories. Measures of effect for health-related patient-reported outcomes (primary outcomes) include subjective, objective, clinically or statistically significant changes in outcomes. Measures of effect for process-related patient-reported outcomes (secondary outcomes) include the proportion of patients who report on decisional conflict or regret associated with using the clinical DSS and the
proportion of users who report adherence to (patients and clinicians) or satisfaction and acceptability with clinical DSS treatment or care recommendations (patients only). As we anticipated a heterogeneous group of studies and outcomes, a narrative synthesis was planned.

3. Results

3.1 Overview of included studies

We included 14 studies in this review published between 2000 and 2021 [26–39] (See Fig. 1, and Table 1). More than half of studies were from the USA (n = 8, 57%) [26–29, 31, 35, 36, 39], with the remaining from Norway (n = 3, 21%) [33, 37, 38] and the UK (n = 3, 21%) [30, 32, 34]. Studies primarily reported on randomized controlled trials (RCTs) (n = 12, 86%) with two studies reporting non-randomized quantitative designs [33, 37]. The majority of studies (n = 10, 71%) reported on DSS that were developed to explicitly monitor and manage patient symptoms and/or pain.

3.2 Quality of included studies

All included studies posed clear research questions and collected appropriate data to enable the research question to be answered. Of the 12 RCTs, 8 (75%) studies performed appropriate randomization procedures, whilst the remaining did not provide adequate detail to determine this. The majority of the RCTs had participants that adhered to their assigned intervention (n = 8, 75%) and comparable data between intervention and control groups at baseline (n = 11, 92%). However, only half of these studies reported complete outcomes data (n = 6, 50%), of which one reported that outcome assessors were blinded to the intervention provided. One of the two non-randomized intervention studies did not adequately report on controlling for confounding variables during analysis of results. Refer to Supplementary Table 2 for detailed quality appraisal of included articles.

3.3 Population

The 14 included studies recruited 5,091 adults (≥ 18 years) patients either receiving or about to receive, cancer treatment, as well as 58 oncologists and nurses as participants. The number of male and female participants across studies cannot accurately be determined due to some studies only presenting baseline data and others only complete outcomes data. The majority of studies included patients with various cancer types (n = 10, 71%) [29, 30, 32–39], with two studies including patients with prostate cancer [26, 27] and two in patients with lung cancer [28, 31]. The largest study was a multi-site study that recruited 1,921 patients with a range of cancers from 19 facilities across the UK [30]. The smallest study, conducted in Norway, involved 52 patients with various metastatic or advanced cancer [33]. Most studies (n = 12, 86%) recruited patients with cancer from clinics and hospitals providing cancer treatment, whilst the remaining two studies recruited from community settings [38, 39].

3.4 Interventions

We subjectively categorized DSS interventions as either symptom assessment interventions or interactive educational interventions based on the purpose and features of the described interventions. The majority of studies (N = 10, 71%) were symptom assessment interventions, subsequently using clinical DSS to monitor and/or report on symptoms-related data entered by patients and/or clinicians [28–30, 32–37, 39]. Of these, eight required clinician input or response to information providers by patients through the DSS [28–30, 32, 33, 35, 36, 39]. The remaining four studies (29%) were interactive educational interventions, primarily intended to guide and inform decision-making regarding treatment [26, 27] and improve patient health-related outcomes such as symptom burden [31, 38], depression and quality of life [38]. These interventions were characterized by the provision of customized information and education to meet the patients’ specific situation, preferences, and/or concerns, as well as communication coaching and support; two of which also provided printed or online teaching materials/reports [27, 31].

Of the symptom assessment interventions, two also provided customized education and information [36, 39] and one of these also incorporated communication coaching and support [36]. Only one study [38] (an educational intervention) was solely patient-facing, whereas the rest (N = 13, 92%) involved both patients and clinicians in collecting data and administering the intervention (patient and clinician-facing) [26–33, 35–37, 39]. Three studies collected data from patients using paper-based tools [29, 30, 33], whilst the others used telephone [39], computer or electronic systems [26, 27, 31, 32, 35, 38] to support tailored recommendations, advice, information or support according to decision rules and based upon individualized need. (Detailed descriptions of each study’s clinical DSS intervention can be found in Supplementary Table 3).

3.5 Outcomes reported

We grouped DSS intervention outcomes into categories where possible. These included 1) health-related patient-reported outcomes (e.g. symptom burden, depression, quality of life, health self-efficacy); 2) process-related patient-reported outcomes (e.g. satisfaction, acceptability and patient/provider adherence); and 3) decisional complexities (i.e. decisional conflict). The DSS interactive educational interventions were the only ones to measure depression [38] quality of life [38], self-efficacy [38], decisional conflict [26, 27]. In contrast, DSS symptom assessment interventions explicitly measured pain [29, 30, 33], global distress [30], as well as patient and clinician adherence to the intervention [29]. Only two (25%) [31, 38] of the eight studies exploring multiple symptom burden were interactive educational interventions, with the remaining being symptom management interventions. Similarly, all but one of the five studies measuring patient satisfaction and intervention acceptability [28, 30, 34, 35] (including ease of use [35] and attention given to mediate symptoms [30]) were symptom assessment interventions. See Table 2 for details of specific tools used to measure a variety of reported outcomes.
3.6 Effects of interventions on outcomes

3.6.1 Primary Outcomes - Health-related patient-reported outcomes

Multiple symptom burden, pain and global distress

Thirteen of the 14 studies (93%) evaluated health-related patient-reported outcomes. Multiple symptom burden was the predominant outcome explored in eight of these studies, six (75%) of which were symptom assessment interventions. Mean symptom severity was reported in 5 (63%), solely symptom assessment interventions. Three studies used custom symptom numerical scales to monitor the severity of symptoms [35, 36, 39], of which two studies (66%) reported statistically and clinically significant reductions in symptom severity in the intervention group compared to controls [36, 39]. One study using the M.D. Anderson Symptom Inventory (MDASI) identified a large reduction in symptom severity between time points within the study, but this was not statistically significant between intervention and control groups [28]. Symptom severity was also significantly reduced for two of six measured symptoms (fatigue and hand-foot syndrome) in the intervention compared to the control group in one study that used a custom measure comprising elements of the Common Toxicity Criteria Adverse Events (CTCAE) and the Chemotherapy Symptom Assessment Scale [32].

A total of three studies (one symptom assessment and two interactive educational interventions) (50%) reported symptom distress [31, 32, 38]. Of the interactive educational interventions, one study consistently reported lower physical symptom distress (measured using the Edmonton Symptom Assessment Scale (ESAS)) in the intervention compared to the control group. Significant differences between groups were observed at 4 months and 6 months, with marginally significant effects observed at 2 months and 8 months [31]. The other interactive educational intervention only identified significant group differences on symptom distress for the Global Symptom Distress (GSI) index of the Memorial Symptom Assessment Form – Short Form (MSAS-SF). Whilst there was a downward trend towards less symptom distress on all subscales and the MSAS-SF total score, and indeed the control group showed a trend towards increased symptom distress – neither were significant [38]. Similarly, a non-statistically significant trend for control group patients to be more distressed by particular symptoms, including fatigue and mucositis, was seen in a symptom assessment intervention [32].

One study also reported on symptom interference as well as symptom threshold events, that is, the number of symptom burden events reported above a certain severity threshold that triggered a DSS recommendation [28]. This symptom assessment intervention significantly reduced overall mean symptom interference in the intervention group compared to control. Additionally, the intervention group experienced a greater reduction in the number of symptom threshold events compared to controls, as well as a more rapid decline in the number of threshold events experienced [28]. Another symptom assessment intervention reported on the number of severe symptom and moderate symptom days, in which the intervention group reduced by 67% and 39%, respectively compared to the control group [36].
Four studies specifically measured the symptom burden of pain using the Brief Pain Inventory (BPI) [29, 33, 37] and the Brief Pain Inventory – Short Form (BPI-SF) [30], all of which were symptom assessment DSS interventions. All four studies reported mean worst and mean usual pain [29, 30, 33, 37]. Half of studies (N = 2) identified a statistically and clinically significant improvement in mean worst pain as a result of the intervention [30, 33]. Further, three of the four studies (75%) investigating mean usual pain identified clinically and statistically significant improvements in the intervention compared to the control group [29, 30, 33]. Subsequently, one study saw no significant improvements in either mean worst or mean usual pain [37]. Additionally, one study reporting on the percentage of patients with controlled pain or mean pain interference, as well as global distress, found no significant differences between intervention and control groups as a result of the clinical DSS intervention [30].

Survival

One study undertook an analysis of intervention users and nonusers in terms of median survival time as a result of participating in the intervention, in which a statistically significant increase in median survival time was identified for intervention users compared to nonusers [31].

Depression, quality of life and self-efficacy

The one interactive educational intervention study exploring depression, health-related quality of life and self-efficacy found no significant differences between intervention and control groups for any of the above outcomes but did achieve significant within-group improvements for depression in the intervention group. Conversely, the control group had significantly worse within-group self-efficacy and health-related quality of life outcomes [38].

3.6.2 Secondary outcomes – process-related patient-reported outcomes

Patient acceptability and satisfaction with the DSS intervention

Intervention acceptability and satisfaction were explored in a total of five studies (36%), in which one was an interactive educational intervention [26] and the rest were symptom management interventions [28, 30, 34, 35]. All five interventions reported high levels of patient satisfaction and acceptability with the intervention [26, 28, 30, 34, 35], particularly in relation to factors including ease of use [28, 35], usefulness [26], as well as the attention given to mediate their symptoms [28, 30, 35]. Contrary, in one study also reporting on clinician satisfaction, only moderate satisfaction was reported regarding the ease of use of the intervention [30]. Additionally, clinician-reported usefulness was also investigated in a single intervention [35]. One study also specifically reported on the participant benefits of participating in the intervention including improved communication with health professionals, improvements in managing their symptoms as well as reassurance that their symptoms could and were being monitored in the home environment [34].

Patient adherence to DSS intervention or recommendations

Three studies, all symptom management interventions, reported on patient adherence to the intervention recommendations [29, 35, 36]. One study specifically investigated patient adherence to prescribed medications in which those in the intervention group were less adherent than control group patients, although this was not a statistically significant difference [29]. The remaining two studies reported on daily phone call adherence required to enter data into the DSS system [35, 36]. Daily call adherence was 65% and 90% for the two studies, respectively [35, 36], and neither of which showed statistically significant differences in adherence between intervention and control groups.

Clinician adherence to DSS intervention or recommendations

Four symptom management interventions specifically investigated clinician adherence to DSS recommendations and this was particularly in relation to medication prescribing [29, 30, 33, 37]. One study identified a statistically significant improvement in overall provider adherence in the intervention group compared to control [29], although did not see significant differences in provider adherence to prescribing of specific groups of drugs including opioids, non-steroidal anti-inflammatory drugs (NSAIDs) or neuropathic co-analgesics. A further two studies also found no significant differences in medication prescribing, specifically for opioids, between intervention and control groups [30] or pre-and post-intervention [37], although the former did report greater improvements generally concerning good practice prescribing as a result of the intervention, compared to controls [30]. The final study reported on changes in prescribing practices, in which clinicians reported making medication changes for 80% and 55% of patients pre-and post-intervention, respectively [33].

3.6.3 Secondary outcomes – decisional complexities

Decisional conflict

In the two interactive educational interventions that explored decisional conflict [26, 27], only one achieved significant reductions in decisional conflict between intervention and control groups, specifically for the ‘uncertainty’ and ‘values clarity’ sub-scales, with a marginal significant effect for overall decisional conflict [26].

4. Discussion

We synthesized data from a total of 14 studies to examine the effectiveness of DSS in improving outcomes for people with cancer. Studies were primarily undertaken in the USA, Norway and the UK, and explored outcomes in patients with various cancer types, or specifically prostate or lung cancer. We categorized and reported on two distinct types of DSS interventions: 10 studies were symptom assessment interventions and four were interactive educational interventions. Whilst symptom burden was measured across both DSS intervention types, specific outcomes with respect to total symptom distress and severity are mixed regarding whether statistically and/or clinically significant improvements were attained, both within and between the two categories of
interventions. The majority of symptom assessment interventions were effective in reducing mean scores for worst and usual pain (solely explored in this type of intervention). However, other health-related outcomes including depression, quality of life and health self-efficacy, explicitly measured in the interactive education interventions, were not effective, and findings were mixed in the few studies that examined decisional conflict. Patient adherence to the interventions was moderate to high and there generally high satisfaction and acceptability, yet there is minimal evidence for the effect of clinical DSS interventions in clinician adherence to intervention recommendations.

Much research to date has promoted the importance and value of using clinical DSS in health and medical settings, however, many reviews exploring the effect of DSS interventions on various outcomes beyond the specific scope of cancer care have also identified heterogeneous effects [10, 14, 15, 40]. Similarly, this review has not demonstrated uniform improvement in patient-reported outcomes across the spectrum of measures investigated, although the evidence is somewhat promising for pain management. There are several potential reasons DSS have not met their expectation of consistently improving patient-reported outcomes in the context of this review and will be discussed below.

In interpreting the results, with respect to patient-reported outcomes, it is important to consider whether DSS interventions are measuring what they should and with the right tools. The interactive educational interventions measured a range of health-related outcomes including depression, quality of life, health self-efficacy, as well as decisional conflict; in which only decisional conflict showed improvement in one study as a result of the intervention. Evidence suggests that enacting improvements in patient health outcomes requires interventions that contain multiple components including a combination of information, reminders, self-monitoring, follow-up and supportive care [41]. However, whilst some of the aforementioned components were administered as part of the studies included in this review, the active intervention components chosen may not always align with appropriate outcome measures. Thus, there may be incongruence between the outcome of interest and the feasibility of the intervention to facilitate the desired improvements. This finding is emulated in research spanning back multiple decades, in which DSS interventions have yet to demonstrate consistent significant improvement in patient outcomes [42–44]. This is potentially attributed to: 1) the type of outcomes measured (eg. a behaviour or decision) [15], 2) whether the context is in acute or chronic health care treatment [45], and 3) whether patients or clinicians are the primary users of the DSS. Whilst we cannot rule out that the interventions simply may not have been effective in improving their targeted outcomes, there is sound evidence that the design and use of clinical DSS interventions are often mismatched with the targeted health outcomes [19].

Further to this, a wide range of outcomes have been investigated across studies. An equally large number of measurement tools have been used to measure the same outcome, particularly in relation to multiple symptom burden and pain, which has been assessed with ten different symptom assessment tools in these 14 studies. This has added to the complexity of interpreting and synthesizing results and ensuring results are truly comparable across studies in terms of specific outcomes being measured, as well as the measure of effect used to determine whether there are improvements in the outcome of interest as a result of the intervention.

There is also a need, therefore, to consistently examine the clinical significance of interventions. Many studies in our review solely investigate statistical significance which has limited meaningfulness in real-world practice. Only a subset of interventions investigating multiple symptom burden or pain measured or reported on the clinical significance of improvements in outcomes. It should be recognized, however, that many of the studies not reporting on clinical significance may not have been powered to do so [17, 19]. This reduces the ability to accurately compare results across studies or discern the effects of individual interventions. It may also be pertinent to consider that reduced patient and clinician adherence to the interventions or recommendations derived from DSS, as seen in several studies, may have contributed to limiting the potential effectiveness of the intervention and subsequently reduced the available evidence of clinical DSS in consistently improving a range of patient-reported outcomes.

The focus of this review was specifically on the effectiveness of clinical DSS interventions for improving patient-reported outcomes in the context of cancer treatment and care. Thus, if an article identified through the search process didn't include patient-reported outcomes, it was not included as part of this review. Given the screening process identified only fourteen eligible studies, this is potentially an indication that DSS interventions still fail to evaluate relevant patient-reported outcomes [19, 40, 42]. Whilst outside the scope of our paper, many articles screened during the study selection process focussed on non-patient related-outcomes including intervention feasibility or clinician-focussed outcomes. Understanding process and feasibility-related outcomes of DSS interventions (beyond those collected from patients) is vital to reducing the wastefulness of research and enhancing its implementation into clinical practice [46]. However, it seems an important gap still exists regarding the true effect and value of DSS interventions in specifically improving patient-reported outcomes in the cancer care setting.

One potentially important application into the future may be how clinical DSS interventions can support individually tailored patient treatment and care. The explosion of information emerging in the precision medicine era means that it will be challenging for individual clinicians to keep updated with all relevant advancements for every individual in their care. Consequently, the ability of clinical DSS to incorporate information such as genomics to support decision-making processes has the potential to help realize the promise of precision medicine in achieving optimal outcomes for individuals [16]. Given the highly values-based nature of precision medicine and the increased need for tools such as clinical DSS that help facilitate shared decision-making processes, further research is warranted [47]. Despite such advances and opportunities, there remains a lack of understanding about the use and impact of DSS on patient-reported outcomes [10, 14, 15]. The use of clinical DSS remains fragmented across cancer care settings, and the extent of the benefits or harms to patients, particularly in relation to patient-reported outcomes is not clear.

Another factor contributing to the heterogeneous effects obtained for patient outcomes synthesized in this review may be the reporting inconsistencies of clinical DSS studies. Undertaking the review highlighted terms related to “decision support systems” and “decision aids” are used interchangeably. The use of the terms interchangeably indicates different understandings, definitions and misuse of terms, meaning that it is not always easy to establish the precise nature of an intervention (i.e. whether indeed a clinical DSS intervention or not). For example, the term “decision aid” is used more broadly and has a longer history compared with DSS to facilitate shared decision-making, however does not always include individual patient characteristics to generate tailored
assessments or recommendations [48]. Further, this is exacerbated by either incorrect indexing of articles when publishing, or inappropriate use of or selection of keywords. This is demonstrated through our systematic search process, which identified many included articles through hand-searching of references lists; highlighting articles were not consistently reported or easy to find and remains an ongoing issue in review article methodology [49, 50].

The majority of DSS interventions synthesized as part of this review focus on multiple symptom burden, particularly in relation to symptom severity and distress, and subsequent treatment/management solutions. It is important to consider both if and how the application of clinical DSS can be expanded to encompass other patient-reported outcomes more broadly in the context of cancer care and treatment. Many limitations exist in relation to the definition, classification and reporting of clinical DSS interventions which may be a pertinent factor contributing to the heterogeneous effects obtained for patient-reported outcomes in this review. Current guidance is absent regarding appropriate reporting of such interventions.

On a broader level, it is also possible that attempts to address health care problems with technological solutions fail to recognize the gap between what is needed and what can be realistically implemented or achieved. Challenges include interoperability and standards for harmonization, integration with clinical workflow, and agreement on the vocabulary and definitions [51, 52]. Indeed only a small proportion of the clinical DSS interventions and other technological solutions that are developed and pilot tested are ultimately implemented into routine clinical practice [52].

A strength of our study is that no other review to date has solely investigated the use and effectiveness of clinical DSS on patient-reported outcomes in the context of cancer care. Whilst other reviews have explored DSS effectiveness in the cancer setting, they have not reported effects on patient-specific outcomes [15, 17] and thus this review bridges an identified and significant gap within the literature. Despite these strengths, there are limitations to be acknowledged. More than half of articles included in this review were identified from hand-searching of reference lists. It is possible that our search strategy was not broad enough to detect these articles during database searches, yet as identified previously, terminology and categorization of articles through the publishing process is also likely to be a contributing factor.

It is proposed this area of research could be enhanced through the development of evidence-based reporting guidelines to accurately and transparently report on the development and testing of DSS interventions in healthcare. The use of guidelines are an integral part of evidence-based practice. Reporting guideline development, therefore, is a critical step in promoting evidence-based practice. Developing and subsequently implementing reporting guidelines would ensure best practice research standards in facilitating and publishing empirical research, enabling greater precision in synthesizing and interpreting interventions and findings [53]. For example, future research would greatly benefit from providing thorough descriptions of DSS systems so that robust assessment of effectiveness and acceptability of system features can be undertaken [54]. We also understand and recognize that the provision of care is becoming more complex. As such, it is imperative to ensure research is targeting, and accurately measuring and evaluating the most important outcomes [55, 56].

5. Conclusion
This review synthesized literature regarding the effectiveness of clinical DSS interventions in improving patient-reported outcomes for people with cancer. It identified two distinct types of DSS interventions, namely symptom assessment interventions and interactive educational interventions. There is good evidence to suggest improvements in pain outcomes including usual and worst pain as a result of implementing clinical DSS interventions, yet effects are mixed for reducing symptom burden outcomes such as symptom severity and distress, and no effect on other health-related patient-reported outcomes such as depression, quality of life, self-efficacy or global distress. Findings from this review highlight the need to develop and implement evidence-based reporting guidelines to inform future consistent and accurate reporting of clinical DSS interventions, including the importance of patient-reported outcomes. Reporting guidelines will enable researchers to design and transparently report on their research, improving the reliability and validity of scientific information and thus improve their timely translation into practice. The potential of DSS interventions to improve patient outcomes in the context of health and medical care cannot be ignored. Thus the development and implementation of guidelines to facilitate accurate and complete reporting of clinical DSS interventions, in conjunction with such interventions adhering to quality reporting standards, is paramount.

Declarations

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The authors declare that they have no competing interests.
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Authors contributions:

All authors contributed to the conceptualisation and design of the research, screening articles, critical review of the paper and approval of the final manuscript. In addition, E.P. performed data extraction, interpretation and synthesis of results and wrote the paper, and N.B. contributed to interpretation and synthesis of results.

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References


**Figures**

![Figure 1](https://via.placeholder.com/150)

**PRISMA flow diagram of review screening process**

**Supplementary Files**

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- PRISMA2020checklist.docx
- SupplementaryMaterialSystematicReviews.docx