Introduction
It is estimated that one in two people in Great Britain will develop some form of cancer during their lifetime [1]. In 2017, 359,000 new cases of cancer were diagnosed in the UK and the rate of incidence is increasing [2]. However, survival rates have doubled in the UK in the last 40 years and so, for many patients, cancer is a chronic condition with which they live for many years [2]. Subsequently, there has been a shift from inpatient to outpatient and community cancer care, where patients are required to manage their condition at home, away from regular supervision by clinicians. This change in care requires patients to take a more active role in their treatment and survivorship. Patients are often faced with an uncertain future, unfamiliar tests and procedures, complex decisions about treatment options, treatment-related side-effects and lifestyle changes. In order to take a more active role in their care, and to cope with and manage these changes to daily life, patients require relevant information [3]. Research has established that patients with cancer have a wide range of information needs throughout their illness. Studies suggest that patients generally want information on the extent of the disease, likelihood of cure and prognosis, available treatments, side-effects of treatment, self-care and return to normal life [4-6]. Other, less urgent, information needs include the impact of cancer and/or treatment on social activities, family and friends, mental wellbeing and sexual activity, and the risk of family and friends getting cancer [4-6]. A need is described as a desire to receive support with an experienced problem [7] and so an information need can be described as the more specific desire for informational support. It is important to note that an information need is separate from other types of needs, such as emotional or practical needs, however information related to other types of illness-related needs can enable patients to meet these other needs. For example, access to information on services that provide psychological support enables patients to contact those services and meet their emotional needs. For the purpose of this paper, the term ‘illness-related information needs’ therefore refers to any type of illness-related information that is needed by a patient, such as information related to the disease itself, treatment, psychological support services, practical support and so on.

While many people with cancer want as much information as possible about their condition and related issues [8], studies across the US and Europe have reported very high rates of unmet information needs [4, 9]. As well as limiting patients’ ability to participate in their care, there is evidence to suggest that unmet information needs are associated with a lower quality of life, losing a sense of control over one’s life, increased anxiety and depression, and dissatisfaction with care [10-13]. The introduction of Smart technology has provided a new platform for delivering information-based interventions to patients. Smart devices, such as Smartphones and tablet computers, are called ‘Smart’ due to their advanced capabilities in comparison to older devices. For example, old generation mobile phones served the sole purpose of sending and receiving communications in the form of text messages and voice calls, whereas the new generation of devices have dramatically enhanced power and
capabilities, and an increasing list of software applications (‘apps’). As well as customised apps, Smartphones and tablet computers are typically equipped with a touchscreen interface, Internet access, digital cameras, music players, GPS systems and much more. Tablet computers typically offer a larger touchscreen interface compared to Smartphones. Most mobile phones that are made and sold today can be described as Smartphones, as even the cheapest, less advanced mobile phones available offer the same types of functions as the most expensive and advanced Smartphones on the market. The more expensive Smartphones and tablet computers are also made affordable by low monthly payment plans.

Apps that are built for Smart devices are able to make use of their enhanced capabilities. Many companies have created apps so that it is easy for consumers to find and use their services and it is now commonplace for people to use apps daily for communication with family and friends, banking, shopping, emailing, gaming or consulting the news and weather [14]. Due to the many advantages of Smart technology, approximately 93% of adults in the UK now personally own or use a mobile phone, of whom 71% specify that they own a Smartphone and over two thirds own or have access to a tablet computer [15]. Importantly, similar statistics of ownership and use have been reported in cancer patient populations [16, 17]. For example, one survey of 210 patients with breast cancer reported that 97% (n=204) of patients owned a mobile, of which 69% (n=145) specified a Smartphone, and 83% (n=174) reported using their mobile phone several times a day, in comparison to a computer by 52% (n=109) [17]. Over half of these patients used their mobile phones for ‘Smart’ activities, such as accessing websites (53%, n=111), emailing (51%, n=107) or planning or scheduling (49%, n=103). As studies highlight the increasing use of Smart devices surpassing that of conventional computers and laptops, it is important to deliver interventions using the platforms that are preferred by patients [17]. Furthermore, interventions delivered via Smart devices have the potential to benefit cancer care due to the wide reach to patients at the point of need and lower cost compared to traditional healthcare interventions, as well as enabling access to tailored healthcare to those in resource-poor settings or those facing access barriers to traditional healthcare [18, 19]. Subsequently, the UK government has encouraged the integration of interventions delivered by mobile technology into traditional healthcare services since the early 2000’s [20]. Furthermore, key reviews over the last few years, such as NHS Five Year Forward [21] and the Wachter review [22], have highlighted the importance of, and urgent push for, digitisation in the NHS, in order for it to continue to provide a high level of healthcare at an affordable cost.

Over the last decade, interventions have been developed and delivered via a range of Smart devices, including Smartphones and tablet computers, as well as older mobile devices, such as old generation mobile phones, Personal Digital Assistants (PDAs) and other ‘handheld’ devices that have enhanced capabilities, such as Internet access and real-time data transmission. This range of devices will therefore be referred to as ‘mobile’ devices throughout this paper, as in the relevant body of literature, as they have been primarily designed to be used when on the move and can be stored away easily on your person due to their compact size. Due to the many advantages of mobile devices, there has been prolific development of ‘mobile’ interventions over the last decade in order to facilitate patients’ self-management of chronic conditions, such as diabetes, heart disease and asthma, where patients are at home, without the supervision of a healthcare professional [23]. Studies have found that these interventions may improve patients’ biological markers of disease, quality of life, communication with clinicians and family, and adherence to medication, whilst
reducing health service costs [23-25]. Following the early indicators of the effectiveness of this type of intervention for other chronic conditions, there has been development of mobile interventions to support patients with cancer.

Several existing systematic and scoping reviews have explored the general use of mobile devices for patients with cancer [26-31]. Findings from these reviews show that interventions delivered via mobile devices have been developed for a range of purposes, including the prevention, detection, and management of cancer; however, most interventions have been designed to support patients during the treatment phase, with fewer interventions developed to assist prevention, diagnosis, follow up and survivorship. However, there has not yet been a review that identifies how interventions delivered via mobile devices have been specifically used to enable patients with cancer to meet their illness-related information needs in non-inpatient settings. The current article therefore presents a systematic review and critical appraisal of studies describing the use of interventions delivered via mobile devices that are designed to enable patients with cancer to meet their illness-related information needs in non-inpatient settings. Specifically, the effects and feasibility of this type of intervention were assessed. This review focused on mobile devices due to the growing number of patients that own this type of technology and the advantages of mobile devices in comparison to older types of technology, such as accessibility (e.g. cost), portability and enhanced capabilities.

Methods
This systematic review followed the PRISMA (preferred reporting items for systematic reviews and meta-analysis) guidelines for the conduct of systematic reviews [32]. The review was registered on the International Prospective Register of Systematic Reviews (PROSPERO) to prevent duplication (registration number: CRD42014010614). At all stages of the search, data extraction and quality appraisal, 10% of studies were independently double checked for consistency by another researcher. Discrepancies were resolved through discussion.

Identification and screening
A systematic search of titles and abstracts was conducted in MEDLINE (1946-2017), EMBASE (1947-2017) and PsycINFO (1806-2017) databases up to January 2017. Search terms focused on three concepts critical to the review question: ‘mobile devices’, ‘information needs’ and ‘cancer’ (Multimedia appendix 1). Terms relating to the same concept were combined using the Boolean operator ‘OR’, and different concepts were combined using the operator ‘AND’. Duplicates were electronically removed using the OVID de-duplicate function prior to review of abstracts. Titles and abstracts of citations were screened for appropriate studies. References of included articles were searched for further studies.

The aim of this review was to assess data on the effects and feasibility of this type of intervention, provided by empirical studies. Prior to the search, it was therefore decided that grey literature would not be searched as these studies are not peer-reviewed and are unlikely to contain empirical data. Identification of studies included a four stage process of identification, screening, eligibility assessment and inclusion [32]. In order to be as inclusive as possible, there were no restrictions on study methodology or date of publication. However, searches were limited to include only human studies and those written in English. Included studies were required to meet the following criteria: 1) interventions were delivered by a mobile or handheld device (e.g. mobile phone, personal digital assistant), 2)
Interventions attempted to meet patients' illness-related information needs, 3) primary participants were patients with cancer who were undergoing treatment, and 4) interventions were for use in non-inpatient settings, or non-inpatient and inpatient settings. Only those participants who currently had cancer were included in this review as cancer survivors may have different information needs to those who are currently undergoing treatment for cancer. Additionally, only interventions that were used to support patients in non-inpatient settings were included, as this is where patients are now primarily managed for the majority of their time during their illness.

Eligibility and inclusion
Searches during the identification stage generated 1,020 citations. A total of 54 articles were considered appropriate for eligibility screening and an additional 14 articles were identified through references. The full-texts of these 68 articles were screened using the inclusion criteria, which resulted in the exclusion of a further 45 articles. Reasons for exclusion of articles are documented in the PRISMA flowchart (Figure 1). As a result, 23 articles were included in the review.

Data extraction and synthesis
Data were extracted onto a template under the following headings; research identification (authors, year of publication, country of study sample, study population), intervention (intervention type, mobile device type), research methods (study design, method, data analysis), outcome measures, principal findings, and quality appraisal. Due to a lack of suitable data, a meta-analysis was not conducted. A narrative synthesis was performed and the findings were organised by common themes found across studies [33].

Quality appraisal
Included studies were assessed for methodological quality using the Critical Appraisal Skills Programme (CASP) checklists for quantitative and qualitative research [34]. The quality of each study was assessed according to each domain included in the checklists, including methodology, design, recruitment, data collection, data analysis, ethical issues, reporting of findings and contribution to research. The overall quality of the studies was categorised as good, medium or poor. The checklists each consisted of ten sections of appraisal questions; one point was assigned for satisfying the criteria for each section, however half a point was awarded for a section if researchers deemed some of the criteria to be satisfied. A total score of 1-5 was considered ‘poor’ quality, 6-7.5 was considered ‘medium’ quality and 8-10 was considered ‘good’ quality.
Figure 1. PRISMA flowchart.
Results

Description of included studies
A total of 20 studies were described by the 23 included articles (Table 1). Within these 20 studies, 14 different interventions were identified. The Advanced Symptom Management System (ASyMS) was used in six studies (described by nine of the 23 articles) and the Cancer Care Home Telehealth intervention (CCHT) was used in two studies (described by two of the 23 articles). The remaining 12 articles described 12 separate intervention studies. Of the 23 articles, there were 13 early-phase feasibility studies, one full RCT, three pilot RCTs, three process evaluations, one matched-case control study, a secondary qualitative analysis of data generated by an RCT included in this review and an analysis of software-logged data from a feasibility study included in this review. Sample sizes of patients ranged from n= 4 to n=125, with 13 studies consisting of 25 participants or less. Of the 23 articles included, twelve were of medium quality, nine were of poor quality and two were of good quality (Table 2, multimedia appendix 2).

Sample characteristics
Patients with a wide range of cancer types were included in studies. A total of 17 studies were of adult patients and three studies were of children or adolescent patients. Ages of adult patients ranged between 24-87 years and ages of child/adolescent participants ranged from 8-18 years. Nineteen studies included non-inpatient participants only. Nine studies provided participants with a mobile device on entry to the study, a further four studies provided devices for participants but participants needed to have a telephone landline in order to participate, two studies required participants to own a mobile device and five studies failed to report whether participants were required to own a mobile device in order to participate in the study or whether a device was provided for the study period. It is also worth noting that one study that provided a mobile device for participants only included those who were ‘able and willing’ to use a mobile device and another study excluded participants if they had poor proficiency with the device.

Description of the interventions

Types of mobile devices
Ten interventions were run on mobile phones; nine of which used Smartphones. One intervention that required participants to use their own mobile phone for the study included both Smartphones and non-Smartphones. Four interventions were run on tablets and two were run on a PDA (a palmtop computer that functions as a personal organiser but also provides access to the Internet). A further four interventions were run on ‘handheld devices’ which were attached to the participants’ telephone line. Studies that used a handheld device did not report the functions of this type of mobile device; however, these devices are typically the most limited device type in terms of functions. Studies published from 2013 onwards used more advanced Smartphones and tablet computers that are commonly used today, such as iPhones and iPads.

Intervention characteristics
Two interventions were primarily designed to directly increase patients’ knowledge of their upcoming surgical operations and coping with cancer-related pain, respectively. One further intervention study primarily aimed to improve patients’ communication of symptoms to clinicians in consultations, thereby facilitating information exchange. The primary aim of the remaining seventeen intervention studies was to improve the monitoring and management of treatment-related symptoms. These interventions provided treatment-related self-care information following patients’ symptom reports and/or included a system where clinicians
would be alerted to contact patients and exchange symptom-related information in order to manage severe symptoms. One of these seventeen interventions also provided cognitive and behavioural skills training in non-pharmacological pain management strategies. Study periods ranged from five days to six months, however some study periods may have been longer due to the duration of participants' treatment, which was not reported.

Table 1. Characteristics of included studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study population</th>
<th>Intervention</th>
<th>Methods</th>
<th>Outcome measures</th>
</tr>
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<tbody>
<tr>
<td>[37]</td>
<td>125 adult patients. Lung, head and neck, colorectal, other cancers. Mean age 63 years. US.</td>
<td>Handheld device, symptom-monitoring for six months. Access to home telephone line required.</td>
<td>Quantitative, matched-case control study. Electronic medical records. Multivariate regression.</td>
<td>Number of preventable service uses (i.e. unplanned clinical visits), and cancer-related service uses (i.e. expected clinical visits) over a six-month period.</td>
</tr>
<tr>
<td>[38]</td>
<td>48 adult patients. Lung, head and neck, colorectal, other cancers. Mean age 64 years. US.</td>
<td>Handheld device, symptom-monitoring for six months. Access to home telephone line required.</td>
<td>Quantitative, feasibility study. Questionnaires, medical records. Descriptive statistics, linear mixed regression.</td>
<td>Patients' cooperation with the intervention (adherence) and health-related quality of life during cancer treatment.</td>
</tr>
<tr>
<td>Reference</td>
<td>Participant Details</td>
<td>Intervention Details</td>
<td>Methodology</td>
<td>Study aims</td>
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<tr>
<td>[39]</td>
<td>20 adult patients, 18 of which had colorectal cancers. Median age 58 years. US.</td>
<td>Tablet computer, symptom monitoring for 6-24 days, depending on time between operation and clinic visit. Mobile device provided (participants excluded for poor proficiency).</td>
<td>Mixed methods, feasibility study. Questionnaires. Descriptive statistics, qualitative data was summarized narratively.</td>
<td>Adherence, patient perceptions of the intervention (effects of the intervention).</td>
</tr>
<tr>
<td>[42]</td>
<td>12 adolescent patients. Leukemia, tumours of the central nervous system. Mean age 12 years. US.</td>
<td>Tablet, pain monitoring for ten days. Mobile device provided.</td>
<td>Quantitative, feasibility study. Questionnaires. Descriptive statistics. One-sample Wilcoxon signed rank tests were performed to determine whether the observed median was equal to the middle value of the scale for each test.</td>
<td>Patient perceptions of the intervention (satisfaction, perceived usefulness), symptom assessment, pain assessment, pain-related coping strategies.</td>
</tr>
<tr>
<td>Reference</td>
<td>Patients</td>
<td>Disease</td>
<td>Age Range</td>
<td>Duration</td>
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<tr>
<td>[43]</td>
<td>44 adult patients</td>
<td>Head and neck cancers</td>
<td>Mean age 59 years</td>
<td>US</td>
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<tr>
<td>[44]</td>
<td>15 adult patients</td>
<td>Lung and colorectal cancer</td>
<td>Age range 24-77 years</td>
<td>UK</td>
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<tr>
<td>[45]</td>
<td>112 adult patients</td>
<td>Breast, lung or colorectal cancer</td>
<td>Mean age 56 years</td>
<td>UK</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Intervention Details</td>
<td>Data Analysis</td>
<td>Patient Outcomes</td>
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<tr>
<td>[50]</td>
<td>15 adult patients. Lung and colorectal cancer. Age range 24-77 years. UK.</td>
<td>Handheld device, symptom-monitoring for two cycles of chemotherapy (approx. 6-8 weeks). Access to home telephone line required.</td>
<td>Software log of activity, descriptive statistics.</td>
<td>Software-logged activity; modem events, questionnaire events, and information access events.</td>
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<tr>
<td>[51]</td>
<td>60 adult patients. Breast cancer. Mean age 51 years. US.</td>
<td>PDA, symptom communication with clinicians, for 160 days (around 5 months). Provision of device unknown.</td>
<td>Mixed methods, pilot RCT. Questionnaires, interviews. Descriptive statistics, random-effects linear regression, qualitative analysis.</td>
<td>Pain, fatigue and depression symptoms, patients' HRQOL and communication self-efficacy. Patients' perceptions of the intervention (effects of the intervention).</td>
</tr>
<tr>
<td>Reference</td>
<td>Participants</td>
<td>Cancer Type</td>
<td>Age/Location</td>
<td>Intervention Details</td>
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<tr>
<td>[56]</td>
<td>26 adult patients</td>
<td>Breast, colorectal cancers</td>
<td>UK</td>
<td>Mobile phone, symptom monitoring for approx. five cycles of chemotherapy. Mobile device provided (participants required to be able to use device).</td>
</tr>
</tbody>
</table>

**Themes**

Findings from the narrative synthesis were organised into two main themes: (1) acceptability of the interventions, which included the subthemes of perceived usefulness, perceived ease of use, and adherence to interventions, and (2) benefits of the interventions, which included the subthemes of symptom management, patient empowerment, reassurance and reduced anxiety,
patient-clinician communication and health-related quality of life (Table 2, multimedia appendix 2).

**Acceptability**

**Perceived usefulness**
The mobile interventions were perceived as useful by the majority of patients, particularly the self-care advice provided in response to symptom reports [36, 41-44, 46, 49, 54, 56, 57]. Qualitative interviews with patients who took part in an RCT reported that the information provided them with expectations for their treatment, reminded them to watch for symptoms and suggested helpful home remedies [43]. Qualitative interviews from another RCT showed that patients were positive about the real-time, fast response of the clinician-alerting facility [49]. However, interviews from a feasibility study found that some patients felt that the depth of the self-care information was insufficient and repetitive [44] and two further feasibility studies revealed variation in use of the self-care advice/information pages [47, 50, 54]. One study reported that whilst over half of patients (62%, n=37 of 60 patients) found a mobile phone, symptom-monitoring intervention useful, patients with lower education and chemotherapy-naïve patients rated the intervention significantly more useful than those with higher education (75%, n=45, vs 35%, n=21) or those who had received chemotherapy before (82%, n=49, vs 53%, n=32) [57].

**Perceived ease of use**
Almost all patients reported that they found the mobile interventions easy to use, regardless of age, cancer type and experience with technology [36, 43, 44, 46, 47, 48, 53-55]. For example, one study reported that all 44 patients from the intervention arm of an RCT reported a handheld device to be very easy (n=37, 85%) or easy (n=7, 15%) to use [43]. Similarly, a feasibility study reported that although 66% (n=12) of 18 patients had little prior computer experience, at post-study all 11 patients who had received the intervention reported that they felt comfortable using the handheld device [44]. A similar study including a sample of 13 patients receiving palliative care reported that patients lacked confidence and experience in using technology, particularly the Internet and PDAs [48]. Post-study, all patients reported that they felt very comfortable (n=6) or comfortable (n=7) using the mobile phone intervention, however five patients required help from family to complete the electronic questionnaire due to poor physical health. Interviews and questionnaire findings from an RCT and feasibility study suggested that daily use of a mobile phone intervention did not impact on patients’ daily routines or privacy and was not perceived as burdensome or too time-consuming [36, 49]. The majority of patients experienced no or very few technical problems with their mobile devices, however those who did tended to encounter problems with Internet connection or practical problems with the device itself [46, 48-51, 55, 56].

**Adherence to mobile interventions**
Studies generally reported high adherence rates to the mobile interventions, regardless of the length of the study [36, 38, 39, 43, 51-53, 55-57]. A pilot RCT of 44 patients reported that patients used a handheld device consistently for an average of 10 weeks [51]. Similar results were reported in another pilot RCT of 60 patients that used a PDA for approximately 22 weeks, where 83% (n=49) of patients completed symptom inventories and 90% (n=54) watched communication videos when instructed [51]. A feasibility study with longest study period included in this review (up to six months) reported that the mean adherence of 48 patients to daily dialogues with a care coordinator using a handheld device was 84%, with a
decrease in adherence as treatment progressed [38]. One study suggested that adherence might be affected by the type of device used or experience with this type of technology, as adherence was significantly higher among Smartphone users compared to basic mobile phones users (87%, n=52, vs 47%, n=28) [57]. The most common reasons reported for non-adherence to interventions were hospitalisation, forgetfulness and technical problems [43, 51].

**Benefits of the interventions**

**Symptom management**

The majority of patients perceived the mobile interventions to be helpful in monitoring their treatment-related symptoms. Additionally, studies highlighted that mobile interventions are able to capture patient information and outcomes that are not captured via conventional reporting, such as questionnaires [39, 42, 44, 46, 48, 52, 54, 56]. However, an RCT of 112 breast, lung and colorectal cancer patients showed mixed results [45]. Authors hypothesised that a real-time, symptom monitoring intervention would facilitate better measurement of six chemotherapy-related symptoms, resulting in more timely interventions. Although two out of six monitored symptoms were significantly different between groups, there were conflicting findings of significantly lower reports of fatigue and significantly higher reports of hand/foot syndrome in the intervention vs. control group. There was some evidence to suggest that symptom-monitoring interventions have the potential to reduce the unnecessary use of healthcare services by improving symptom management [36, 37, 56]. For example, a matched case-control study of 125 patients investigated the effects of a handheld device intervention by measuring patients’ unexpected and expected use of cancer-related services over six months [37]. Findings showed that the intervention group had significantly lower use of unexpected care services and significantly higher use of most expected care services, however contrastingly, patients in the intervention group had significantly fewer expected clinic visits compared to controls. Authors suggested this contrasting result was possibly due to patients resolving issues with the care coordinator prior to an expected clinic visit thereby reducing the need for the visit.

The majority of symptom-monitoring intervention studies further reported that patients perceived that the interventions had led to improved symptom management [39, 43, 46, 47, 49, 52, 56]. A process evaluation from an RCT of 44 patients found that 52% (n=23) reported that they were much better, and 44% (n=19) somewhat better, at managing their condition as a result of a handheld, symptom-monitoring intervention [43]. A more recent feasibility study reported that participants showed significantly decreased pain severity, physical symptoms, psychological distress, and pain catastrophizing following a tablet-run pain-coping skills intervention [52]. Similarly, a feasibility study of a mobile phone intervention [36] reported that the mean pain score of participants from the start to end of a feasibility study decreased non-significantly, but when measured using the European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30), the mean pain score decreased significantly from 56 to 35. Furthermore, two studies reported that patients were admitted to hospital as a result of a real-time symptom monitoring intervention, which resulted in proactive management of those patients’ symptoms [36, 56].
Patient empowerment

Some studies suggested that remote monitoring of symptoms empowered patients to participate in their care and better manage their condition due to increased knowledge of their condition and symptom management strategies provided by the mobile interventions [39, 42-44, 56]. In qualitative interviews with 11 lung and colorectal cancer patients, patients explained that this type of intervention had increased their understanding of their symptom-related problems and consequently, their confidence in their abilities to manage symptoms [44]. Furthermore, six patients that used a mobile phone, symptom-monitoring intervention reported that they felt more involved and responsible for their care [55]. More recent studies supported these results [52, 56]. A feasibility study of a mobile phone intervention reported that patients felt more in control of their care and had increased confidence to self-manage their condition at home as a result of the intervention [56]. Similarly, a feasibility study of a tablet device intervention showed that out of 25 patients, 95% (n=20) reported that the intervention helped them to understand the experience of pain and 90% (n=19) of participants felt the intervention had taught them skills that improved their pain coping; however, an observed increase in pain self-efficacy following the pain-related coping skills intervention was not significant [52]. Finally, a similar feasibility study of a tablet device intervention [42] reported on the perceived usefulness of pain management strategies used by children, including self-talk, heat application and social support and suggested that this type of intervention provided patients with the opportunity to increase their self-efficacy in coping with pain during treatment.

Reassurance and reduced anxiety

The majority of studies reported that patients perceived clinicians’ surveillance of, and response to, their symptoms as reassuring, however there were some mixed findings for the effects of information on levels of anxiety [40, 41, 44, 46-49, 54-56]. Qualitative interviews with 12 patients from a process evaluation of an RCT of a mobile phone, symptom-monitoring intervention reported that patients felt secure in the knowledge that clinicians were being alerted about their symptoms [49]. Results from a secondary analysis of these interviews suggested that patients viewed their surveillance as liberating, freeing them of the worry of making a decision to contact clinicians themselves [41]. Similar perceptions were reported by patients in a smaller pilot RCT, where patients felt the mobile phone intervention allowed them to relax [46]. In contrast, a feasibility study of a mobile symptom monitoring intervention reported no change in anxiety levels [47] and one study suggested that information interventions may increase patients’ anxiety [40]. A pilot RCT study of a tablet-based information provision intervention found that there was a significant increase in pre-operative fatalism in the intervention group and anxiety was significantly lower in the control group at seven days post operation [40]. This study suggests that increasing patients’ knowledge of treatment could potentially increase rather than reduce their anxiety. However, authors reported that some women were anxious about using a tablet computer with which they were unfamiliar and this may have increased their anxiety [40]. Additionally, the follow up period was short at seven days post-surgery.

Patient-clinician communication

Many patients perceived that communication with clinicians had improved or that their relationship with clinicians had strengthened as a result of the interventions [35, 39, 41, 43, 46, 47, 55]. A post-study questionnaire of 44 patients from an RCT of a handheld, symptom-monitoring intervention found that 65% (n=29) of patients were more satisfied with the communication with their clinicians [43]. A secondary qualitative analysis of patient
interviews from an RCT of a mobile phone, symptom-monitoring intervention reported that patients felt the intervention gave them easier access to cancer specialists, as well as increasing the amount of communication with clinicians [41]. Authors suggested that easier access to clinicians may change the dynamic of the traditional hierarchical models of healthcare to a more patient-centred model, as clinicians are more responsive to the patients’ reports and needs. Furthermore, two feasibility studies found that as the intervention prompted clinicians to contact the patients, patients’ uncertainty about whether to contact their clinicians when needed was reduced and they felt less ‘bothersome’ to their clinicians [47, 55].

**Health-related quality of life (HRQOL)**

Studies reported mixed findings of the interventions on patients’ HRQOL [36, 38, 43, 47, 51]. An RCT of 44 patients using a handheld device during treatment periods, which required patients to report symptoms three to five times daily, reported significant positive correlations between usage of the intervention and physical well-being and emotional well-being scores during treatment [43]. A feasibility study of 48 patients using a handheld device to answer daily symptom questions from a care coordinator found a clinically significant improvement of 6.3 points in patients’ HRQOL between baseline and six months [38]. This study suggested that a symptom-monitoring intervention could reassure patients who are anxious during treatment, thereby maintaining their HRQOL. In contrast, although one feasibility study reported a non-significant increase in quality of life following a pain-monitoring intervention [36], one feasibility study reported no change in wellbeing [47], however both studies had small sample sizes. Negative findings were also reported in a pilot RCT study of 60 patients using a PDA device, where patients reported symptoms weekly during treatment periods and viewed videos on how to communicate their symptoms to their clinicians prior to their consultations [51]. This study found that patients’ HRQOL were not significantly different between groups. Furthermore, the pre-post treatment decrease in HRQOL was generally greater among the intervention group. Authors suggested that this result might be due to the intervention drawing attention to the symptoms experienced by patients in the intervention group [51]. However, due to the methodological differences between studies, such as study design, measurement of HRQOL and intervention intensity (e.g. intervention functions, interaction with patient and duration of intervention), meaningful comparison of these studies is not possible, though it is possible that intervention intensity is partly responsible for these mixed findings.

**Discussion**

**Principal Results**

To our knowledge, this is the first systematic review to identify and critically appraise studies that describe the use of mobile interventions designed to enable patients with cancer to meet their illness-related information needs in non-inpatient settings. The primary aim of the majority of intervention studies included in this review was to improve the monitoring and management of patients’ treatment-related symptoms, which included the provision of self-care information and interactive information exchange with clinicians. Although these interventions attempted to educate patients in some way, the information and skills provided were solely related to their treatment. There were no interventions that primarily aimed to meet patients’ full range of illness-related information needs by increasing their understanding of their condition and other important, related issues.
Overall, findings from this review indicated that patients reported this type of technology and intervention to be acceptable, regardless of age, experience with technology, cancer type or stage of cancer. Patients perceived the mobile interventions to be useful, particularly the self-care advice and the fast response from clinicians. Additionally, there was evidence to suggest that patients with lower education or chemotherapy-naïve patients could benefit most. Patients also reported that they found the mobile interventions easy to use and non-intrusive on their daily routine, with few technical problems encountered. Adherence to interventions was generally high, however there was considerable variation in usage of the different intervention components within and between studies. Reported benefits of the interventions included improved symptom management, patient empowerment and improved clinician-patient communication, however mixed findings were reported for patients’ anxiety and HRQOL.

**Findings in the context of other literature**

A plethora of mobile interventions have been developed to support patients remotely with a range of chronic conditions, such as diabetes and heart disease, and findings of the present review mirror this previous literature which has found mobile technology to be an acceptable platform to deliver interventions to patients with chronic conditions, regardless of the patients’ type of disease, age, gender and experience with technology [23-25]. The finding that few technical problems were experienced in the present review is in contrast to previous literature, where many patients have cited technical difficulties as a barrier to use and satisfaction with the intervention [58-60]. This contrast finding may be due to the fact that many interventions for other conditions, such as diabetes and heart disease, require additional technological devices to monitor symptoms (e.g. glucose monitor, blood pressure monitor), which would increase the likelihood of technical errors.

Adherence rates to mobile interventions included in this review were generally high throughout the study periods, which were up to six months, however engagement appeared to decrease over the course of the intervention. These patterns mirror those of studies of mobile interventions for other chronic conditions, which included study periods of 12 months [60]. Despite generally high rates of adherence for this type of intervention, there appears to be considerable variation in usage of the different intervention components within and between studies, such as the self-care advice pages. It is important that future studies better describe interventions by coding intervention functions in order to determine the components that are responsible for positive outcomes and enable more systematic evaluations [61].

Patients recognised the benefits of real-time symptom monitoring interventions, such as increased knowledge and confidence to participate in self-care, which appeared to result in improved management of symptoms. Additionally, the capability of this technology to capture patient-reported outcomes in real-time may be of clinical importance as it promotes timely intervention [60, 61]. This could reduce the amount of preventable hospitalisations, as suggested by some studies included in this review. Previous studies of mobile symptom-monitoring or adherence interventions have shown similar findings, including improvements to symptoms, such as an increased blood glucose control, increased self-management behaviours, such as increased adherence to treatment, and fewer hospital admissions [23-25, 60].

In the present review, patients reported that communication with their clinician had improved as a result of the interventions and that found clinicians’ monitoring of their
symptoms to be reassuring. Similar findings have been reported in studies of symptom-monitoring interventions for other chronic conditions, where patients described feelings of security, felt that they had not been forgotten and were receiving good care outside of hospital and clinics [62, 63]. Mobile interventions offer an inexpensive way to bridge the gap between patients and clinicians and increase their contact at a time when patients require more support following a shift from inpatient to outpatient cancer care.

Findings of the present review reported mixed findings on the impact of mobile interventions on patients’ anxiety and HRQOL, however few studies included in this review measured these outcomes. For some patients, having more knowledge on their condition might reduce their anxiety due to the development of realistic expectations of the future and preparedness for treatment-related side effects, resulting in a better experience. Conversely, information might also increase patients’ anxiety by drawing attention to their condition, unknown symptoms or the risks of treatment. The few studies that have measured the impact of mobile devices on patients’ quality of life or emotional distress for other chronic conditions have also reported mixed findings [64, 65]. However, some studies have highlighted the potential of Smartphones to specifically increase patients’ awareness of stress and emotional well-being, by recording moods during both health and illness, and deliver therapeutic interventions accordingly, which has led to reduced anxiety [65, 66]. Mobile interventions can provide an opportunity to increase patients’ access to psychological support and deliver psychological interventions remotely at a time when patients are vulnerable.

**Quality of studies**

The large number of early-phase studies in this field means that many studies included in the present review used an uncontrolled design. The current evidence for the effectiveness and feasibility of mobile interventions to support patients with cancer is therefore limited. Although these studies highlighted the potential benefits of such interventions, RCTs are needed to support the findings of this review. Additionally, most studies included in this review were critically appraised as poor or medium quality, which further limits the conclusions that can be drawn from these studies. Limitations of some studies included small sample sizes, samples limited to single cancer types, under-reporting of response rates and details of participants who were lost to follow up, and short study periods. Other limitations included the failure of studies to explore the opinions of patients with negative views and the economic costs of these types of intervention. Additionally, some studies only included participants who had access to their own device or were already able to competently use a mobile device. This inclusion criterion may have biased findings, as those who participated in these studies may have had more favourable perceptions of mobile interventions than those who were unable to participate. Finally, many studies relied on self-reported data which may have been affected by recall or the Hawthorne effect [67], where participants may have changed their behaviour due to knowingly being observed.

**Strengths and limitations of this review**

The AMSTAR checklist (A Measurement Tool to Assess Systematic Reviews) was used to assess the quality of this systematic review. Strengths of this review include an ‘a priori’ design, ten percent of studies at each stage of the search, data extraction and quality appraisal was checked for consistency by another researcher, multiple databases and references of included studies were searched, study characteristics were reported, and the studies were critically appraised on their quality, which was taken into account when drawing conclusions. However, the present review has several limitations. A meta-analysis
was not conducted as included studies did not have suitable data to aggregate, however a narrative synthesis was considered to be a suitable alternative method to explore the findings of these studies. Other limitations include poor indexing of studies, which may have limited the number of studies included in this review, and a number of potential studies were found through searching references of included studies. Finally, this review did not report on the perceptions and experiences of healthcare professionals that participated in some studies as this was beyond the scope of the review.

**Implications for policy and practice**

This review has several implications. Firstly, it established that a wide range of patients with cancer perceived mobile devices to be an acceptable medium to receive interventions remotely. Secondly, this type of intervention appears to have the potential to provide a range of benefits for patients, clinicians and the healthcare service. Specifically, findings of this review suggest that symptom-monitoring interventions that provide treatment-related information to patients have the potential to improve patients’ self-management of their condition and provide clinicians with a better understanding of patients’ symptom experiences, whilst improving the patient-clinician relationship. This may lead to earlier detection of treatment-related side-effects and timely intervention, which could reduce costs for the healthcare system. This type of intervention also has the potential to sustain or improve patients’ well-being during a time where they typically experience a decrease in well-being. Importantly, this review established that, to date, mobile interventions for patients with cancer have only attempted to meet a single type of information need (e.g. treatment-related symptom information, coping skills), which has typically been achieved indirectly.

This review has also identified that more comprehensive interventions are required for patients currently receiving treatment in order for them to meet their full range of illness-related information needs in non-inpatient settings, where they are now spending the majority of their time away from the direct supervision of their clinicians. The literature has established that the type of illness-related information required by patients with cancer varies within and between patients with cancer and any unmet information needs will likely depend on the information provided by their healthcare team. It is therefore unlikely that a single intervention can include this large amount of information in a single intervention and tailor it to an individuals’ condition and location for related services. However, there already exists a huge number of useful and reputable cancer-related information resources and services throughout the UK, such as information websites, telephone helplines, support groups, and financial services, which are developed and run by reputable cancer charities and health organisations. Intervention developers could incorporate and organise existing services within interventions in order to arm patients with the tools that they need to be able to obtain relevant information.

The majority of interventions identified in this review required continued monitoring and interaction from clinicians, however involving clinicians places unrealistic demands on an already stretched healthcare service. Few mobile interventions have been developed to be used independently by patients. Development of such an intervention would support the initiatives of UK governments and health organisations to empower patients to take a more active role in their care by increasing support for patients in non-inpatient settings and harnessing the power of technology in order to do so [21, 22].
Conclusions
This is the first systematic review to identify how mobile devices have previously been used to help patients with cancer to meet their illness-related information needs in non-inpatient settings. So far, the majority of mobile interventions have been designed to enable clinicians’ surveillance of patients remotely in the form of symptom-monitoring interventions. Despite promising findings, these interventions have sought only to increase patients’ knowledge of their treatment-related side-effects and coping strategies. More comprehensive interventions are required for patients who are currently receiving treatment in order to meet their full range of illness-related information needs when managing their condition in non-inpatient settings. Given the variation of information needs within and between patients, it may be useful for intervention developers to incorporate existing cancer-related information resources and services into interventions in order to enable patients to obtain their desired information. Nevertheless, mobile devices appear to be an acceptable platform to deliver interventions remotely to patients with cancer. This review also highlights the early stage of the research that is being conducted in this area, which limits the conclusions that can be drawn. Following on from early-phase feasibility studies, RCTs are needed to support the findings of this review, further determine the effectiveness of this type of intervention to improve patient outcomes and to support the transfer of interventions into standard practice.

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Conflicts of Interest
None declared.

Abbreviations
HRQOL Health related quality of life
PDA Personal digital assistant
PRIMA Preferred reporting Items for systematic reviews and meta-analysis
RCT Randomised controlled trial

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