Can clinical prediction tools predict the need for computed tomography in blunt abdominal? A systematic review

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Abstract

Introduction

Blunt abdominal trauma is a common reason for admission to the Emergency Department. Early detection of injuries is an important goal but is often not straightforward as physical examination alone is not a good predictor of serious injury. Computed tomography (CT) has become the primary method for assessing the stable trauma patient. It has high sensitivity and specificity but there remains concern regarding the long term consequences of high doses of radiation. Therefore an accurate and reliable method of assessing which patients are at higher risk of injury and hence require a CT would be clinically useful. We perform a systematic review to investigate the use of clinical prediction tools (CPTs) for the identification of abdominal injuries in patients suffering blunt trauma.

Materials and Methods

A literature search was performed using Medline, Embase, The Cochrane Library and NHS Evidence up to August 2014. English language, prospective and retrospective studies were included if they derived, validated or assessed a CPT, aimed at identifying intra-abdominal injuries or the need for intervention to treat an intra-abdominal after blunt trauma. Methodological quality was assessed using a 14 point scale. Performance was assessed predominantly by sensitivity.

Results

Seven relevant studies were identified. All studies were derivative studies and no CPT was validated in a separate study. There were large differences in the study design, composition of the CPTs, the outcomes analysed and the methodological quality of the included studies. Sensitivities ranged from 86-100%. The highest performing CPT had a lower limit of the 95% CI of 95.8% and was of high methodological quality (11 of 14). Had this rule been applied to the population then 25.1% of patients would have avoided a CT scan.

Conclusions

Seven CPTs were identified of varying designs and methodological quality. All demonstrate relatively high sensitivity with some achieving very high sensitivity whilst still managing to reduce the number of CTs performed by a significant amount. Further studies are required to validate the results obtained by the highest performing CPTs before any firm recommendation can be used regarding their use in routine clinical practice.

Introduction

Blunt abdominal injury (BAT) is common and is associated with intra-abdominal injury (IAI) in 8-17%[1-4]. Early detection of these life threatening injuries is critically important. Physical examination alone is not a good predictor of IAI[5-8]. Significant, life threatening injuries can be present in the absence of obvious clinical signs[2,8]. This is especially true in the presence of a head injury or other distracting injuries[7,9].

Computed tomography (CT) has become the primary method for investigating the stable trauma patient. The sensitivity and specificity of CT for identifying IAI is high at 96-100% and 94-100% respectively[10-14] and it has a very low rate of missed injuries[12]. However, the pick-up rate from such scans if often very low[15]. One study suggested that as few as 1% of haemodynamically stable patients with BAT have significant IAI[16]. Other studies have suggested that stable BAT patients without clinical evidence of IAI can be safely managed without CT[17-19].

Increasingly whole-body CT (WBCT) is being used as a form of triage[20-22]. Supporters have argued that WBCT enables more rapid diagnosis and therefore earlier treatment and that it leads to fewer missed injuries[23-27]. Opponents will argue that it can delay intervention, is more expensive and exposes patients to higher radiation doses[28-29].

A number of studies have attempted to demonstrate a benefit to unselected WBCT[30-40]. Most of these studies agree that unselected WBCT reduces time to diagnosis, time to surgery and time spent in the Emergency Department[30-32,35,41]. Its use has been shown to reduce mortality in patients with impaired consciousness and haemodynamic instability[33,36]. Of course, demonstrating the utility of WBCT in high risk patients (such as those with impaired consciousness and haemodynamic instability) is not the same as proving it is appropriate for patients without obvious signs of injury. Gupta et al found there was a very low incidence of clinically relevant abnormalities when WBCT was performed in the absence of a specific clinical indication[38].

Only one study has specifically studied the use of routine WBCT in haemodynamically stable patients with no signs or symptoms of injury[37]. It claimed that 7.1% of abdominal CT scans showed clinically significant findings. However, most of these injuries were relatively minor and it is unknown how many of these injuries may have been suggested by physical examination or bedside diagnostic studies.

Increasingly, concerns have been raised about the risks posed by excessive use of CT. Ionising radiation is a known carcinogen and is associated with a number of malignancies[42,43]. Much of the evidence behind this comes from non-medical radiation exposures[44-46], but there is evidence to suggest that exposure to doses of 10-100mSv (the range more relevant to medical imaging) can increase the risks of malignancy[47]. Compared with conventional radiography, CT exposes patients to

significantly higher radiation doses and these doses have been shown to increase substantially when liberal trauma CT policies are implemented[48].

Lifetime risks vary from 1 in 1250 in a 45 year old patient undergoing a whole body CT to 1 in 250 for a 20 year old woman undergoing an abdominal CT[49,50]. The risks are significantly higher in paediatric patients and young adults due to their increased susceptibility to radiation[51-53].

A clinical prediction tool (CPT) is a tool designed to guide clinicians in making management decisions[54]. They combine multiple independent variables to create a score which can be useful in establishing a diagnosis or in deciding on further investigations or treatment options[55]. They are commonly used for determining the need for head and cervical spine imaging after trauma[56-60].

This study aims to perform a systematic review of the literature looking at the use of CPTs aimed at identifying lower risk blunt trauma patients who can be managed without the need for a CT scan of the abdomen. We aim to identify and evaluate the methodological quality and the clinical performance of existing CPTs used in adults with BAT.

Methods

A systematic review and meta-analysis was performed. This was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) recommendations[61].

English language, prospective and retrospective studies were included if they derived, validated or assessed a CPT aimed at identifying IAI (all injuries or clinically relevant injuries only), or the need for intervention to treat an IAI after BAT. For the purposes of this study, a CPT was defined as: a tool which includes three of more variables and where the presence of any one of these variables renders the CPT positive. The variables may be obtained from the history, physical examination or from simple diagnostic tests available at the bedside in the Emergency Department (arterial or venous blood analysis, urinalysis, plain x-rays or focussed assessment with sonography in trauma (FAST) scan).

Studies were excluded if they: assessed the predictive value of individual variables only; assessed the predictive value of variables without the intention of creating a CPT; included only patients under the age of 18; or included patients with penetrating trauma.

A literature search was performed using Medline, Embase, The Cochrane Library and NHS Evidence up to August 2014. The search was performed using combinations of keywords such as: clinical prediction tools; computed tomography; CT scan; blunt abdominal trauma; blunt abdominal injury; intra-abdominal injury (see Appendix 1 for full search strategy). In addition to the above databases, studies published in four core journals (Annals of Surgery, European Journal of Trauma and Emergency Surgery, British Journal of Surgery and Journal of Trauma and Acute Care Surgery [previously known as the Journal of Trauma, Injury, Infection and Critical Care]) since January 2004 were hand searched. The reference lists of included studies were also searched manually for additional studies.

Studies identified by the search strategy above were screened for inclusion using a two-step process. Firstly, the titles and abstracts of each study were assessed. Secondly, the full text was assessed for studies which were thought to be potentially relevant and studies where relevance remained uncertain.

Data collected included: details on study design; the inclusion and exclusion criteria used in each study; the indications for performing a CT scan; the predictor variables included in the CPT; the outcome measures used; sensitivity, specificity, positive (PPV) and negative predictive values (NPV) and the proportion of patients who would have received a CT had the CPT been implemented.

The included studies were assessed using a 14 point scale adapted from published guidelines used for the derivation of CPTs[62-66]. The 14 questions asked of each paper can be seen in Table 2 (for more details see Appendix 2). For each item a mark of 0 was awarded if the criteria was not fulfilled (or if it could not be ascertained from the

paper whether the criteria was fulfilled) and a mark of 1 awarded if it was fulfilled. The maximum total score was therefore 14.

CPTs assessing the presence of an injury were assessed separately to those assessing the need for acute intervention. For the purposes of determining the most effective CPT it is assumed that sensitivity is considered the most important single measure.

Stats Direct version 3.0.141 (StatsDirect Ltd., Altrincham, UK)) was used to analyse data. Sensitivity, specificity, PPV and NPV were expressed as a percentage with 95% confidence intervals. Individual predictors were expressed as odds ratios with 95% confidence intervals. Pooled odds ratios were calculated using the Dersimonian-Laird random effects model[67]. A p-value of less than 0.05 was considered statistically significant. Heterogeneity was expressed using I^2, where values of 25%, 50%, and 75% correspond to cut off points for low, moderate, and high degrees of heterogeneity.

Results

The literature search produced 72 results. Figure 1 shows the PRISMA flow diagram detailing the process of study selection. Ultimately the process produced seven studies which were included in the final analysis[1,15,68-72].

Table 1 describes the study designs and population characteristics of the seven included studies.

Methodological quality of the studies is summarised in Table 2. All studies adequately described the study setting and the predictor variables. All studies also produced tools which were clinically sensible and adequately reported their results. The areas which were most infrequently fulfilled were the blinding of those reporting the outcomes (0 of 7), blinding of those assessing the predictor variables (1 of 7), reproducibility of the predictor variables (1 of 7) and the application of the tool to all patients at risk (2 of 7).

Inclusion and exclusion criteria for each study are described in Table 1. A number of studies sought to exclude patients who were clearly more seriously injured. Some excluded patients who were haemodynamically unstable, others excluded patients with reduced Glasgow Coma Scale (GCS). One paper excluded patients who presented in cardiac arrest or who arrested in the emergency department[15]. Two studies excluded patients when the GCS was 10 or below[68-69]. One study excluded patients with class III or IV shock or those requiring immediate surgery[70]. Two others excluded patients with systolic blood pressure (SBP) on admission of less than 90mmHg[68,69].

The studies took different approaches to the use of CT scanning. Most studies included only patients who underwent a CT scan[1,68,70,71]. However, only one study adequately described their indications for performing a CT[70]. One study included only patients who underwent a 'definitive diagnostic test', however this could be CT, diagnostic peritoneal lavage (DPL) or surgical intervention (laparotomy or laparoscopy)[15]. Two studies included all patients, including those not undergoing a definitive investigation[69,72]. The majority of patients in these studies underwent DPL rather than CT.

Most of the studies looked at a single CPT[69-72]. One study looked at a single CPT for the identification of IAI and a separate CPT for the need for acute surgical or radiological intervention[15]. One of the studies analysed the same data with four different CPTs[1]. Another analysed two separate CPTs[68], using CPTs adapted from the studies by Mackersie[72] and Grieshop[69], included in this review. Therefore in total 11 CPTs are analysed.

The variables included in each study are described in Table 3. The only variable included by all authors was chest injury, although the definition of this differed between studies. Only one author did not include an abnormal abdominal examination[72]. Similarly, one of the CPTs analysed by Garber et al[68] (based on the

CPT designed by Mackersie et al[72]) did not include an abnormal abdominal examination. Some authors specifically included only abdominal tenderness[15,71].

All authors defined IAI as their primary outcome, with four papers including the need for intervention as a secondary outcome[1,15,70,71]. The definition of IAI varied between studies. Most studies included solid organ injuries (spleen, liver, kidney, pancreas, adrenal) and hollow viscus injuries (bowel, colon, bladder, ureter), vascular injuries to major intra-abdominal vessels, the presence of pneumoperitoneum and the presence of significant intra-abdominal free fluid[1,15,69,71,72]. One study also included fractures of the pelvis and lumber spine[70]. One study chose not to include bowel injuries[68].

The need for acute intervention was generally defined as the requirement for operative or interventional radiological intervention[1,15,71]. One study additionally included the requirement for fracture fixation or stabilisation and the need for further diagnostic radiological investigations[70].

Across all seven studies there was significant variation in the incidence of injury. The lowest incidence of IAI was 5.5%[71] and the highest 36.7%[68].

Four papers included evaluation of the predictor variables individually[1,15,69,72]. Table 4 summarises the results for the seven variables analysed by more than one author. All seven are associated with significantly increased risk of IAI. A SBP of less than 90mmHg had the highest odds ratio followed by the presence of an associated chest injury and the presence of a lower haematocrit.

All studies described CPTs used for the assessment of risk of IAI. In total there were eleven CPTs analysed. Sensitivity, specificity, PPV and NPV for each of the CPTs are described in Table 5. The sensitivities ranged from 86% to 100%. Specificity ranged from 11.8% to 100%. The NPV ranged from 95.5% to 100%. If these tools were applied to all patients then the frequency of which CT scans would have been ordered ranged from 26.5% to 89.7%.

The three highest performing CPTs based on sensitivity were all from the same study, the highest having a sensitivity of 100%[1]. The next best performing study had a sensitivity of 97.4%[15].

If the lower limit of the 95% confidence interval (CI) is used, the poorest performing CPT had a lower limit of the 95% CI of just 59.7%[71]. The highest performing CPT had a lower limit of the 95% CI of 95.8%[15]. Had this tool been applied to the population then 25.1% of patients would have avoided a CT scan.

Four studies described CPTs used for the assessment of the need for acute intervention[1,15,70,71]. In total there were seven CPTs analysed. Sensitivity, specificity, PPV and NPV for each of the CPTs are described in Table 6. The sensitivities ranged from 96% to 100%. Five of the seven CPTs reached a sensitivity of 100%[1,15,71]. Specificity ranged from 11.0% to 34%. The NPV ranged from 99.0% to 100%. If these

tools were applied to all patients then the frequency of which CT scans would have been ordered ranged from 67% to 90%.

Once again, the highest performing CPT (using the lower limit of the 95% CI for sensitivity) was the study by Holmes et al[15]. The sensitivity of this study had a lower limit of the 95% CI of 97.2% and 26.0% of patients would have avoided a CT scan had this CPT been applied.

Discussion

We have identified seven studies, producing eleven different CPTs. When the lower limit of the 95% CI for sensitivity is used the best performing CPT for the presence of IAI had a sensitivity of 97.4% (95% CI: 95.8-99.3%) and would have scanned 74.9% (95% CI: 73.6-76.1%) of patients (Table 5)[15]. This was also the study with the highest methodological quality score (11/14).

Four studies also used their CPTs to assess the requirement for acute intervention. Three of the CPTs produced by Poletti et al[1] had sensitivities of 100%, however the lower limit of their 95% CI was low between 83.4-84.0% (Table 6). Holmes et al[15] also had a sensitivity of 100% (95% CI: 97.2-100%) but with a much more impressive lower confidence limit.

Neither of these CPTs include any measure of haemodynamic stability[1,15]. Therefore, in theory, a hypotensive patient may fail to trigger the tool. A potential reason for this may be that these patients are more likely to bypass the CT scanner and go straight to the operating room for definitive management and therefore would be less likely to be included in the study population. Clearly, it would be unacceptable for clinicians to not investigate such a patient.

To assess methodological quality we used a checklist involving the use of 14 factors considered to be important for the development of CPTs[62-66]. A number of quality issues were particularly poorly met; probably the most important of which was the failure to perform a CT scan for all patients at risk. Understandably, it is not necessarily desirable to scan every patient and authors overcame this problem in various ways. Some studies included all patients who presented with BAT but did not perform a CT scan on all included patients[69,72]. Others included only patients who underwent CT[1,68,70,71].

Our systematic review demonstrates that even the poorest performing CPT achieved a sensitivity of 86.0%[72] with most studies achieving a sensitivity of comfortably over 90.0%. Few of the studies included in this review analysed missed injuries but those that did, did not identify any injury missed by their CPT which required any intervention[15,70,71]. It would therefore appear possible to devise a CPT which, if used appropriately, will accurately identify higher risk patients in need of further investigation whilst missing very few injuries. The widespread use of similar CPTs for determining the need for imaging of the head and neck in trauma would suggest that this is a realistic aspiration[56,57,73,74].

There is debate regarding the significance of missed injuries with no consistent definition in the literature of what constitutes a clinically important missed injury[75]. Some authors describe observation as a necessary intervention however it could be argued that observation of a trivial injury is unnecessary[37,75]. CPTs are unlikely to ever achieve 100% sensitivity for the identification of all injuries but the identification of the vast majority of injuries requiring intervention would appear achievable. It should also be noted that CT scanning itself does still miss injuries and

that actually the better performing CPTs identified in this study have sensitivities very similar to those described for CT scanning[10-14]. A period of clinical observation will remain necessary for some patients (including some patients with a negative CT scan) and clinical decisions on imaging and discharge would be aided by more research focusing on criteria for the selective use of CT and clinical observation.

Performing routine WBCT is expensive and exposes large numbers of patients to potentially harmful doses of radiation. These risks are only justified if they are outweighed by the benefits and there is little evidence in the literature that this is the case for haemodynamically stable, fully conscious patients with no clinical signs or symptoms of injury. We have identified CPTs which have the potential to identify lower risk patients with a high degree of sensitivity and reduce significantly the number of patients requiring CT imaging. Whilst the majority of patients will still require CT, this is probably justified for higher risk patients[33,35,36,40]. It is reasonable, however, to attempt to reduce the need for CT in lower risk patients and the use of well validated CPTs would seem an ideal way to achieve this.

Any study such as this has inevitable limitations. As is demonstrated in Table 2, the methodological quality of included studies is not high and the ability of any systematic review is limited by the quality of the included studies. The aim of this study was to attempt to review the evidence for CPTs which can determine whether a blunt trauma patient with few signs of serious injury requires an abdominal CT scan. In truth, few of the studies truly address this question as none robustly exclude patients with evidence of more severe injury. Such a study is problematic because any such study aiming to derive or validate a CPT, should include a gold standard reference against which the CPT should be assessed. Clearly a CT scan is the reference standard against which a CPT aimed at identifying IAI should be assessed. However, including only patients undergoing CT (as many studies included in this review have done) is likely to result in a group of patients with a higher risk of injury (as lower risk patients are less likely to be selected to undergo CT). The alternative approach, taken by some studies, is to include all patients but accept that not all will undergo a CT and rely instead on less accurate diagnostic tests or on clinical follow up only. This approach is then limited by the lack of a gold standard reference test.

In addition, all of the included studies are performed in the equivalent of Level 1 trauma centres and mostly in North America. This potentially limits the applicability of any conclusions to centres elsewhere, where the type of trauma experienced and the demographics of the population may differ, and to Emergency Departments which deal with a lower volume of trauma cases, where the staff may be less experienced. This emphasises the importance and need for studies to validate the results of potential CPTs in different populations.

Finally, the heterogeneity of the included studies makes direct comparison of them difficult. They differ in their patient selection, variables included in the CPTs, reference values and even in what is considered an intra-abdominal injury.

Conclusions

Although a number of the CPTs identified in this study appear to show promise, none have been validated in different environments or different populations and so it is impossible to recommend one particular CBT for routine clinical practice. Further studies should concentrate on attempting to validate existing CPTs in different populations.

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