

1 Poor specificity of National Early Warning Score (NEWS) in
2 spinal cord injuries (SCI) population: A retrospective cohort
3 study

4 Running title: Poor specificity of NEWS in SCI population

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21 **Structured Abstract**

22 Study design:

23 Retrospective chart audit.

24 Objectives:

25 The National Early Warning Score (NEWS) is based on seven physiological parameters which can be
26 altered in some individuals with spinal cord injuries (SCI). The aim was to start the development of
27 adapted NEWS suitable for SCI population. The objective was to determine the SBP NEWS
28 specificity based on neurological level of injury (NLI) and completeness of injury.

29 Setting:

30 Tertiary centre in the UK.

31 Methods:

32 Adult patients admitted for the first time to the National Spinal Injuries Centre between 1st January
33 2015 and 31st December 2016 were included if they were > 6 months post-injury. Data were collected
34 retrospectively including the last ten consecutive BP and heart rate readings before discharge. Data
35 were analysed based on different AIS grades, completeness of injury and NLI.

36 Results:

37 191 patients were admitted in 2015 and 2016 and 142 patients were included in the primary analysis.
38 The mean SBP ranged between 92 and 151 mmHg. Patients with the NLI of T6 and above (\geq T6)
39 motor complete lesions had a significantly lower SBP than motor incomplete lesions. The specificity
40 of the SBP NEWS was 35.3% in \geq T6 motor complete individuals versus 80.3 % in \geq T6 motor
41 incomplete individuals.

42 Conclusion:

43 The baseline BP is significantly lower in the \geq T6 motor complete chronic SCI individuals resulting in
44 a very low specificity of 35.3 % to SBP NEWS which could lead to mismatch between clinical
45 deterioration and NEWS resulting in lack of timely clinical response.

46

47 **Introduction**

48 The level and degree of injury directly results in disruptions of cardiovascular control in spinal cord
49 injuries (SCI) population [1]. As a result, some SCI result in altered parameters in respect of vital
50 signs. The most notable change in baseline vital signs is an immediate drop in systolic blood pressure
51 (SBP) following high SCI as a result of neurogenic shock. However, following the acute stage, there
52 is a group of patients that continues to suffer from cardiovascular dysfunction. A meta-analysis [2]
53 showed the higher the neurological level of injury (NLI) the greater the degree of cardiovascular
54 dysfunction. Individuals with lesions to the cervical cord have been reported to have a 15 mmHg
55 lower resting SBP in a seated compared to supine position [2]. This can be explained by disruption of
56 descending input to the sympathetic preganglionic neurones that occurs with lesions at the level of T6
57 and above (\geq T6) [3, 4]. This in turn results in loss of the splanchnic blood vessels tone, which leads
58 to long lasting hypotension post injury [3, 4].

59 A systematic review of the SCI literature [5] suggests that there is no clear consensus that resting BP
60 differs between neurologically complete and incomplete patients. However, as the descending
61 vasomotor pathways are anatomically located adjacent and dorsolateral to the lateral descending
62 motor corticospinal tract [6], it is not unreasonable to hypothesise that neurological completeness of
63 injury may be related to cardiovascular dysfunction [6].

64 Several studies [7, 8, 9, 10, 11, 12, 13, 14, 15] reported results of daytime baseline BP. Some of them
65 reported low baseline SBP (\sim 110 mmHg) mainly in individuals with motor complete tetraplegia [8,
66 9], whereas others [13, 15] reported low baseline SBP (\sim 103 mmHg, 111 mmHg) in individuals with
67 motor complete and incomplete tetraplegia. Another study [14] reported low baseline SBP (\sim 109
68 mmHg) for C4 – T12 motor complete injuries. To the contrary, two studies [7, 10] reported a higher

69 SBP of ~ 118 mmHg in individuals with incomplete tetraplegia whereas another study [11] reported
70 even a higher SBP of ~ 124 mmHg in individuals with complete tetraplegia. One study [15] reported a
71 supine SBP of 113 mmHg in autonomically–complete SCI compared to supine SBP of 128 mmHg in
72 autonomically–incomplete SCI.

73 An important implication of cardiovascular dysfunction is in recognising and responding to a
74 deteriorating in-patient. In the United Kingdom, the Royal College of Physicians (RCP) National
75 Early Warning Score (NEWS) [16] has been adopted across the National Health Service (NHS) to
76 identify early clinical deterioration in a patient. The NEWS scoring system is based on seven
77 physiological parameters; respiratory rate, oxygen saturation, oxygen use, SBP, pulse rate, level of
78 consciousness and body temperature. A score is allocated to each parameter, with zero assigned to a
79 normal value and deviation triggering scores of 1 – 3 for each parameter. Scores are then added, and a
80 combined NEWS score of 5 or more requires an urgent medical response. Whilst the system has been
81 found to be effective and is a recommended surveillance system for all patients in hospitals [16], it is
82 recognised that the NEWS may be unreliable in SCI, especially patients with tetraplegia or high
83 paraplegia. Disruption of the autonomic nervous system and resulting fluctuations in pulse rate,
84 temperature or blood pressure BP may lead to low sensitivity of the NEWS [16]. Indeed Asafu-
85 Adjaye and Gall [17] flagged a low sensitivity of NEWS in patients with tetraplegia and paraplegia as
86 well as low specificity in patients with tetraplegia. However, their study didn't stratify injuries based
87 on NLI or neurological completeness of injury. Despite clear advocacy for the use of a standard
88 system for assessing and responding to acute illness [16], there is no evidence to form the basis for
89 bespoke and valid guidance in the management of patients with SCI with different lesions in acute
90 and ambulance settings.

91 This retrospective cohort study of patients with SCI was thus conducted to determine the SBP NEWS
92 specificity based on NLI and completeness of injury and subsequently lay down the foundations for
93 development of adapted NEWS suitable for this population.

94

95 **Methods**

96 Participants and Experimental Design

97 Patients with an SCI, admitted for the first time to the National Spinal Injuries Centre (NSIC) between
98 01/01/2015 and 31/12/2016, were eligible if they were adults (≥ 18 years) and >6 months from injury.
99 Patients were excluded if they (a) were deemed to be clinically unwell by their treating doctor, or (b)
100 died during their admission, or (c) were not yet discharged at the time of the study, or (d) did not have
101 discharge NLI or AIS grade available, or (e) did not have observation charts available. This study was
102 preliminary retrospective chart audit therefore a priori sample size estimation was not performed and
103 the number of cases during the study period determined the sample size. Due to the study's
104 retrospective nature, the clinical observations and determinations of NLI and AIS grade were made
105 without being influenced by the study; in this manner observer bias was minimised. Data collected
106 were observed by two clinicians in an attempt to reduce investigator bias.

107 Data Sources

108 This study used electronic medical records – Irish Medical Systems (IMS) and Evolve – of the NSIC,
109 a tertiary specialist centre with a capacity of 103 SCI beds. IMS contains both clinical notes and
110 neurological examination findings. Evolve contains all paper documents including NEWS observation
111 charts, discharge summaries and International Standards for Neurological Classification of Spinal
112 Cord Injury (ISNCSCI) charts [18]. Using the unique NHS number of each patient, these data were
113 cross referenced with clinical observation records stored in Evolve. The STROBE statement and
114 checklist were used, plus RECORD extension was considered to guide study reporting.

115 Demographic data obtained from the NSIC coding department included NHS numbers, date of birth,
116 age, sex, date of injury, admission and discharge dates. Ideally, neurological examination using the
117 ISNCSCI chart is conducted for all patients on admission and prior to discharge and stored on IMS
118 and Evolve. Admission and discharge NLI and AIS grades were obtained from ISNCSCI charts and
119 discharge summaries. Data were collected on confounding factors such as the number of patients on
120 antihypertensive, antiarrhythmic or medications with known hypotensive effects.

121

122 Blood Pressure Recordings

123 Cardiovascular function was determined using NEWS chart developed by the RCP. The NEWS2
124 chart is the latest version approved in 2017 with no changes to the SBP NEWS chart (Figure 1). These
125 charts had been completed during admission by either nurses or health care assistants. BP
126 observations were obtained with the patient in a supine position using the Mindray (Shanghai, China)
127 automated sphygmomanometer (portable and fixed) and the portable Welch Allyn (New York, USA)
128 automated sphygmomanometer. These observations were obtained at least twice per day (morning and
129 evening prior to sleep) in the NSIC during routine practice on each of the four different adult wards.
130 The last ten BP and pulse rate observations prior to discharge were obtained from Evolve. These BP
131 readings were taken over a period of 5 – 7 days as at times there were missed readings on particular
132 days as many individuals spend 1 – 2 days out of the NSIC during weekends.

133 (Figure 1 here: not available in this manuscript)

134 Statistical Analysis

135 All data were analysed using the Statistical Package for Social Sciences (version 25; SPSS Chicago,
136 IL). Normality and homogeneity of variance were confirmed by the Shapiro–Wilk and Levene’s test,
137 respectively, where appropriate. Mean BP and co-efficient of variation for the ten last BP
138 observations before discharge were calculated for each individual and used in subsequent analysis.
139 Individuals were further assigned the NEWS that related to their mean SBP. A score of zero assigned
140 to a normal value and deviation from the normal value triggering scores of 1-3. For data analysis,
141 patients were assigned as triggering either a (1) normal value (NEWS of 0) or (2) a deviation from
142 normal (NEWS 1 or 2). Specificity refers to the percentage of patients who were correctly diagnosed
143 using SBP NEWS as not triggering because of their mean SBP reading, i.e. triggering SBP NEWS 0.
144 For the main analysis, groups were formed according to AIS grades (A-D), motor complete (AIS A
145 and B) and motor incomplete (AIS C and D). A sub-analysis was performed considering level of

146 injury ($\geq T6$) and motor index score (MIS) (0-25, 26-50, 51-100). The MIS is the sum of all key
147 muscles motor scores. These bands of MIS were chosen based on clinical hypothesis that (a) MIS 0 –
148 25 would include a majority of patients with motor complete tetraplegia, (b) MIS 26 – 50 would
149 include a mixture of patients with motor incomplete tetraplegia and motor complete paraplegia, and
150 (c) MIS 51 – 100 would include a majority of patients with motor incomplete tetraplegia and
151 paraplegia. Between group differences were determined using a one way ANOVA with post hoc
152 analysis conducted using pairwise comparisons with a Bonferroni correction for continuous data and
153 chi-squared tests (χ^2) from the cross tabs procedure for NEWS score categorical data. Significance
154 was accepted at an alpha of 0.05.

155

156 **Results**

157 The total number of new admissions to the NSIC in the calendar years of 2015 and 2016 was 191.
158 Figure 2 shows of the 191 new admissions, 142 patients, who had complete data, were included in
159 analysis. Most of the 142 patients ($n = 135$) were admitted for specialist rehabilitation < 1 year post-
160 injury with a mean of 85 days (range 6 – 297 days). Only three patients were admitted between 1 – 3
161 years and four were admitted > 3 years post-injury for fixed admission to address specific
162 rehabilitation goals.

163 (Figure 2 here: not available in this manuscript)

164 Systolic Blood Pressure:

165 The total number of SBP readings analysed was 1420 and the mean SBP ranged from 92 to 151
166 mmHg. Demographic data of the 142 patients included in the primary analysis are displayed in Table
167 1.

168 (Table 1 here: not available in this manuscript)

169

170 ASIA Impairment Scale

171 Co-efficient of variation showed intra-individual variability was low (SBP mean: CoV
172 0.09 ± 0.04 mmHg) demonstrating patient BP was stable over the ten observations. ANOVA
173 revealed a significant difference in SBP between AIS grades, with SBP lower in AIS A than
174 AIS C ($p = 0.03$) and AIS B lower than AIS C ($p = 0.001$) and AIS D ($p = 0.003$). The AIS
175 grade of a patient had a significant effect on their SBP triggering of NEWS score, when
176 analysed using a patient's AIS grade ($\chi^2 = 25.47$, $p < 0.001$) or according to the motor
177 completeness of their injury ($\chi^2 = 23.55$, $p < 0.001$). 59.1% of patients with a motor complete
178 injury (AIS A & B) triggered a NEWS score (1 or 2) compared to 18.4% of those with motor
179 incomplete injuries (AIS C & D). Therefore, the specificity of the SBP NEWS was 40.9 % in
180 the motor complete group compared to 81.6 % in the motor incomplete group. Comparison of
181 the mean SBP, diastolic BP (DBP) and mean arterial pressure (MAP) of different AIS groups
182 is shown in Table 1. The difference in the NEWS specificity between the motor complete
183 group and motor incomplete group is clinically relevant and significant.

184 Neurological Level of Injury and Motor Completeness

185 ANOVA found SBP was significantly lower in the group of patients with NLI \geq T6 ($n = 98$,
186 117 ± 12 mmHg) compared to those with NLI $<$ T6 ($n = 44$, 123 ± 14 , $p = 0.07$). ANOVA
187 also found in the group of patients with the NLI \geq T6, the motor complete patients ($n = 34$,
188 111 ± 12 mmHg) had a significantly lower SBP than motor incomplete patients ($n = 64$, $120 \pm$
189 12 mmHg, $p = 0.001$), but no significant difference in the mean SBP of tetraplegia (C1 – C8)
190 individuals (111 mmHg) when compared to high paraplegia (T1 – T6) individuals (109
191 mmHg) in those who were \geq T6 motor complete injuries. For patients with NLI \geq T6, motor
192 completeness had a significant effect on a patient's NEWS ($\chi^2 = 19.06$, $p < 0.001$). 64.7 % of
193 \geq T6 motor complete patients (62.5 % in tetraplegia group and 70% in high paraplegia group)
194 triggered NEWS of 1 or 2 compared to 19.7 % of the \geq T6 motor incomplete. As a result, the
195 specificity of the SBP NEWS was 35.3% in \geq T6 motor complete patients (37.5% in

196 tetraplegia group and 30% in high paraplegia group) and 80.3 % in \geq T6 motor incomplete
197 patients. The difference in NEWS specificity based on NLI (\geq T6 versus $<$ T6) stratification
198 and motor complete versus motor incomplete injuries is the most meaningful and clinically
199 significant finding that conforms with our clinical findings since the introduction of the
200 NEWS by the RCP in 2012.

201 Motor Index Score (Sum of All Key Muscles Motor Scores)

202 Out of the 142 patients, 83 patients had discharge MIS available including 55 with NLI \geq T6
203 and 28 with NLI $<$ T6. The mean MIS was 33 in \geq T6 motor complete compared to 64 in \geq
204 T6 motor incomplete individuals. In comparison, the mean MIS was 59 in $<$ T6 motor
205 complete compared to 83 in $<$ T6 motor incomplete individuals. The majority (89 %) of
206 individuals with MIS (0 – 25) had motor complete tetraplegia, whereas, the majority (81 %) of
207 individuals with MIS (51 – 100) had motor incomplete tetraplegia. Further details of
208 numbers of individuals and mean MIS in each AIS group is detailed in Table 2.

209 (Table 2 here: not available in this manuscript)

210 In the NLI of T6 and above group (n= 55 patients), the SBP tended to be lower in patients
211 with a MIS (0-25) (108 ± 12 mmHg) compared to MIS (26-50) (116 ± 13 mmHg) and MIS
212 (51-100) (120 ± 11 mmHg), though this did not reach significance on ANOVA ($p = 0.08$). A
213 patient's MIS score had a significant effect on their NEWS ($x^2 = 11.58$, $p = 0.003$). Out of the
214 55 patients that had a discharge MIS, 67.3 % had a NEWS of 0. 62 % of patients with NEWS
215 0 had a MIS of (51 – 100), whereas 50.0 % of patients with NEWS 1 or 2 had MIS (26 – 50).
216 Within the MIS (0 – 25) group, 83.3 % triggered NEWS 1 or 2, whilst 85.2 % of the MIS (51
217 – 100) group had NEWS of 0 (table 2). The differences in SBP and percentage of NEWS
218 trigger based on MIS bands emphasize the clinical relevance of difference based on motor
219 completeness noted in the previous sections.

220

221 National Early Warning Score (NEWS) and Hypothetical Systolic BP Spinal Cord Injury –
222 NEWS

223 From our data, we have noticed that by dropping the lower normal SBP in the NEWS chart
224 from 111 mmHg to 101 mmHg, the mean SBP of the majority of individuals with \geq T6 motor
225 complete lesions would move from NEWS score of 1 to a NEWS score 0 (Figure 3).

226 (Figure 3 here: not available in this manuscript)

227 In order to have a more accurate, reflective and specific SBP NEWS chart that helps to better
228 identify the risk of clinical deterioration with timely intervention for \geq T6 motor complete
229 patients specifically, we propose a new Spinal Cord Injury SBP NEWS (SCI-NEWS) chart
230 (Figure 4). This new chart was synthesized by adapting the current SBP NEWS chart by
231 introducing two new cut-offs for lowest (101 mmHg) and highest (149 mmHg) normal SBP.
232 The new lowest normal SBP was based on the improvement of specificity as shown in Figure
233 3. The new highest normal was based on the recommended SBP of 150 mmHg as guidance
234 for introduction of medical treatment of autonomic dysreflexia. The SBP SCI – NEWS chart
235 would generate similar trigger scores (0, 1, 2, and 3) which are added to the 6 other
236 parameters (respiratory rate, O2 saturation, O2 supply, pulse rate, consciousness and
237 temperature) scores to generate the NEWS aggregate. This is then assessed with the same
238 NEWS thresholds and triggers which will be applicable to assess clinical risk and response
239 (Table 3). Application of the SCI-NEWS systolic BP monitoring chart on the mean SBP
240 readings of our cohort improved the specificity from 35 % to 82 % (from 38% to 79% in
241 tetraplegia group and from 30% to 90% in high paraplegia group). Comparison between the
242 SBP NEWS and SBP – SCI NEWS scoring systems is given in table 4.

243 (Figure 4, table 3 and table 4 here: none available in this manuscript)

244

245

246 Pulse Rate:

247 A total of 1420 pulse rate readings (last 10 readings for each patient) were analysed. ANOVA found
248 no significant differences noted between motor complete and motor incomplete individuals in the \geq
249 T6 lesions or those $<$ T6. In the group of \geq T6 lesions, the mean pulse rate was 72 beats/min (71
250 beats/min in tetraplegia versus 75 in high paraplegia) in motor complete individuals compared to 74
251 beat/min (73 beats/min tetraplegia versus 79 beats /min in high paraplegia) in motor incomplete
252 individuals. Whereas, in the group of $<$ T6 lesions, the mean pulse rate was 76 beats/min in motor
253 complete individuals compared to 78 beats/min in motor incomplete individuals. These results
254 showed no clinical significance or meaning as none of these readings would trigger any NEWS score.

255

256 **Discussion**

257 The results of this study confirm that altered cardiovascular function results in lower BP in some
258 patients with an SCI. To our knowledge this is the first large scale study to provide preliminary data
259 describing typical BP responses reporting on how this affects the NEWS based on SBP whilst being
260 clinically well. Our findings suggest that the \geq T6 motor complete lesions have lower baseline SBP
261 and subsequently lower NEWS specificity compared to the \geq T6 motor incomplete lesions.

262 Common causes of low SBP in individuals with SCI include orthostatic hypotension, dehydration and
263 sepsis. However, our data and that of others [2, 19] suggest that some individuals with an SCI have
264 low baseline SBP when they are well. Autonomic dysreflexia is an emergency autonomic condition
265 due to sympathetic hyperactivity resulting in increasing severe hypertension typically in \geq T6 patients.
266 It happens more commonly, but not exclusively, in patients who are motor complete usually as a
267 result of a trigger below the patient's NLI. Common triggers include bladder and bowel distention. A
268 sudden increase of 20 – 40 mmHg in BP above the baseline may be a sign of autonomic dysreflexia
269 [20] and requires treatment if the SBP exceeds 150 mmHg.

270 The present study's findings may have important implications for detecting and responding to
271 deteriorating SCI patients. The RCP's NEWS score [16] has shown to be proficient at discriminating
272 risk of serious clinical deterioration and acute mortality as the best existing systems and better than
273 most [24]. The only paper that has discussed the relationship of the current NEWS and SCI patients
274 was a letter [17] to the RCP reporting an audit conducted in the London Spinal Injuries Centre. In
275 their audit of NEWS records from 100 patients, the authors [17] studied the sensitivity (the ability of
276 NEWS to trigger urgent clinical reviews for unwell patients i.e. score of ≥ 5) and the specificity of
277 the NEWS (the ability of NEWS not to trigger urgent clinical reviews for well patients i.e. score of \leq
278 4). Forty-nine patients with tetraplegia and 51 patients with paraplegia were included with a
279 sensitivity of 63 % for patients with tetraplegia compared to 35 % for patients with paraplegia and a
280 specificity of 37 % for patients with tetraplegia compared to 100 % for paraplegia. The NEWS missed
281 37 % of un-well patients with tetraplegia whose main pathology was autonomic dysreflexia and
282 surprisingly it also missed 65 % of un-well patients with paraplegia which included cases of
283 pulmonary embolism and viral illness. Their results were skewed by the lack of stratification using
284 NLI and AIS grades. In comparison, our study showed a specificity of 35.3 % in \geq T6 motor complete
285 patients.

286 Further analysis, albeit using the available MIS data (55 patients), emphasized the significant
287 association between the motor function and NEWS score as 67.3 % with MIS score did not trigger
288 NEWS (i.e. NEWS 0). In addition to that, 83.3 % of those with low MIS (0 – 25) were motor
289 complete and the majority of that group (83.3 %) triggered NEWS 1 or 2. On the other hand 100 % of
290 those with high MIS (51 – 100) were motor incomplete patients and the majority of that group (85.2
291 %) did not trigger NEWS (i.e. NEWS 0). These results confirm that the current SBP NEWS chart may
292 not be reliable for \geq T6 motor complete patients with 35.3 % NEWS specificity. This would certainly
293 affect the overall cumulative NEWS score consequently affecting the patients at risk of clinical
294 deterioration and the facilitation of timely and effective response. Therefore, our study has identified
295 the \geq T6 motor complete patients as a group of largest concern using the current NEWS. To the
296 contrary, the NEWS has a high specificity of around 81% in motor incomplete patients which

297 suggests that it is possibly valid to use in this group of patients. The mean SBP for the majority (92
298 %) of our patients was between 101 – 149 mmHg and the maximum recorded was 151 mmHg.
299 Treatment of autonomic dysreflexia using anti-hypertensive medication is widely recommended for
300 high SBP of 150 mmHg and above [20]. Based on our study results, 64.7 % of \geq T6 motor complete
301 patients triggered SBP NEWS score when they were well with only 35.3 % specificity. Therefore, we
302 proposed a hypothetical SBP SCI – NEWS as detailed in the results section.

303 The effect of SCI on cardiovascular function is best understood in the acute setting. Tuli et al 2007
304 [21] demonstrated higher SBP and heart rate in motor incomplete patients following acute cervical
305 cord injury and showed greater incidence of neurogenic shock in motor complete compared to motor
306 incomplete patients. In addition, studies have shown a greater prevalence of persistent bradycardia
307 and hypotension in motor complete injuries [19, 22]. Our results of low baseline SBP (111 mmHg) in
308 \geq T6 motor complete lesions are similar to other reports in the literature [8, 9] which reported low
309 baseline SBP (~ 110 mmHg) in individuals with motor complete tetraplegia. Although we did not
310 have data on autonomic completeness of injury, our results are also comparable to the study [15]
311 that reported a supine SBP of 113 mmHg in autonomically–complete SCI. In contrast, our results
312 showed a lower baseline SBP to the one (~ 124 mmHg) reported by Frisbie et al [11] in individuals
313 with complete tetraplegia. Even when our SBP data of the \geq T6 motor complete lesions were split into
314 tetraplegia (C1 – C8) and high paraplegia (T1 – T6), the baseline SBP was still low averaging 111
315 mmHg and 109 mmHg successively. These results were contrary to those of Rosado-Rivera et al [12]
316 and of Goh MY et al [14] which showed relatively higher baseline SBP (115 mmHg and 117 mmHg).
317 Similar to other studies [9, 10, 11, 12], our data showed relatively higher baseline SBP (123 mmHg)
318 in the group of low paraplegia (NLI < T6). It is worth empathizing that our study population of 142
319 patients is very large compared to the population of the aforementioned single studies (excluding
320 meta-analysis and systematic review). Whilst there is less evidence in chronic injury, a meta-analysis
321 by West et al. [2] demonstrated that patients with a higher NLI have the lower BP and heart rate. Our
322 results of lower mean SBP in those with NLI of \geq T6 are consistent with the finding of the meta-
323 analysis. However, our data also demonstrated that low BP was associated with \geq T6 motor complete

324 injuries. This is due to the disruption of descending input to the sympathetic preganglionic neurons
325 that control the vital splanchnic vascular bed leading to long-lasting hypotension post-injury [22]. The
326 descending vasomotor pathways are located adjacent and dorsolateral to the lateral corticospinal tract
327 [6], and hence motor complete patients (with motor tract injuries) are more susceptible to autonomic
328 cardiovascular dysfunction. A recent systematic review [5] suggested that autonomic completeness is
329 more strongly correlated to cardiovascular function than neurological completeness of injury. As the
330 present study was retrospective and there was no autonomic test (such as sympathetic skin response)
331 routinely performed in these patients, the relationship between autonomic completeness and
332 cardiovascular function was not studied.

333 Limitations of our study include single centre, retrospective design and relatively high percentage (25
334 %) of patients excluded, which could all add to the risk of bias. Possible confounding factors that
335 could affect BP recordings were inadequate resting time after physical activity, possible bladder and
336 bowel distention prior to recordings. These could not be controlled given the retrospective nature of
337 the study. A major limitation of the study is exclusion of other chronic SCI who were re-admitted for
338 instance for orthopaedics /plastics /urology procedures or even top-up rehabilitation. The intention of
339 the study was to analyse the SBP data after all the SCI patients had well passed the phase of spinal
340 shock, i.e. > 6 months post-injury. It should also be considered that patients on anti-hypertensive
341 medication (or medicines with hypotensive effects) were included but the proportion of those in all
342 AIS groups was similar (25 %) apart from those in the AIS A group (14.3 %). The retrospective use of
343 records also resulted in the lack of available discharge MIS data (43 absent records in the \geq T6 group).
344 Another limitation is the small number ($n = 34$) of \geq T6 motor complete patients which meant the
345 study power was lower in this sub analysis.

346 In conclusion, the study has identified that patients with \geq T6 motor complete injuries have low
347 specificity for the NEWS SBP chart. Based on our results, an adapted SCI-NEWS SBP chart was
348 synthesized resulting in improvement of the NEWS specificity from 35% to 82%. However, further
349 research is required to validate the SCI-NEWS and determine whether sensitivity is also improved.
350 To do this, a large scale prospective multicentre trial would be recommended. In addition, the

351 relationship between autonomic completeness and motor completeness of injuries could be explored
352 further by performing an autonomic test such as sympathetic skin responses in this group of patients.

353

354

355 **Data Archiving**

356 All data generated or analysed during this study are included in this published article [and its
357 supplementary information files].

358

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361 the data collection. We would also like to extend our special thanks to our medical staff team
362 colleagues in the National Spinal Injuries Centre who provided peer support and contributed to
363 discussions about the proposed SCI – NEWS.

364

365 **Statement of Ethics**

366 No ethical approval was required for our study as this was a retrospective observational study.
367 Patients' confidentiality and anonymity were fully respected in data handling and storage.

368

369 **Conflict of Interest Statement**

370 The authors declare no conflict of interest.

371

372 Author contributions

373 WA has contributed to the study design, data collection, data analysis, drafting and revising the
374 manuscript, approving the final version and takes accountability for all aspects of the work. AR has
375 contributed to the study design, data collection, data analysis, drafting and revising the manuscript,
376 approving the final version and takes accountability for all aspects of the work. KG has contributed to
377 the statistical analysis (i.e. important role interpreting the results), revised the manuscript, approved
378 the final version and takes accountability for all aspects of the work. JC has contributed to the
379 statistical analysis (i.e. important role in interpreting the results), revised the manuscript, approved the
380 final version and takes accountability for all aspects of the work. HD has contributed to the statistical
381 analysis (i.e. important role in interpreting the results), revised the manuscript, approved the final
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383

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386

387 Supplementary Material

388 1. SCI – NEWS data sheet (Excel file) includes anonymized study participants individual baseline
389 data, collected blood pressure and heart rate data as well as data analysis tables (spread over 9 pages).

390 2. KG data analysis 3.7.18 (pdf file) includes main body of statistical data analysis.

391 3. 2018_10_12 data analysis (word document) includes further data analysis (4 pages).

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463 Figure Legends

464 Table 1: Demographic data of patients included in primary analysis.

465 Table 2: Motor Index Score Data Analysis

466 Table 3: NEWS thresholds and triggers

467 Table 4: SBP Trigger Scores Comparison of NEWS Systolic BP versus SCI – NEWS Systolic BP

468 Figure 1: Systolic blood pressure (SBP) and pulse National Early Warning Score NEWS2 chart

469 Figure 2: Overview of patients' selection process for primary analysis

470 Figure 3: Systolic blood pressure (SBP) National Early Warning Score (NEWS) chart showing mean

471 SBP readings of patients with NLI \geq T6 motor complete lesions and their relationship with the cut-off

472 lowest normal SBP in NEWS and SCI – NEWS charts

473 Figure 4: Spinal Cord Injury (SCI) – National Early Warning Score (NEWS) Systolic blood pressure

474 (SBP) monitoring chart