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Original Research

A clinical prediction score to determine surgical drainage of deep neck infection: A retrospective case-control study

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ABSTRACT

Background: The objective of this retrospective study was to identify predictors of an abscess guaranteed to be surgically drained successfully in patients with deep neck infection (DNI).
Materials and methods: We divided 97 consecutive patients with DNI into a drained group and a non-drained group. We then developed a clinical prediction score and validated it in 32 further patients.
Results: Significant predictors of successful surgical drainage (i.e., positive for pus) were rim enhancement on computed tomography, C-reactive protein, erythrocyte sedimentation rate, and the neutrophil to lymphocyte ratio. The estimated cut-off values (excluding rim enhancement, which is a yes/no parameter) were 41.25, 56.5, and 8.02, respectively, and the clinical prediction score for each of the four other factors was determined to be 2, 2, 3, and 3 points, respectively. The cut-off score for the sum of these points was 6.5 and the scoring system had an accuracy of 87.5% in the validation group.
Conclusion: Our clinical prediction scoring system can predict whether drainage is successful in patients with DNI.

1. Introduction

Deep neck infection (DNI) is a life-threatening condition localized in the potential spaces and fascial planes of the neck, such as the retropharyngeal, danger, prevertebral, parapharyngeal, carotid, submandibular, and sublingual spaces [1]. DNIs can have severe complications, including airway obstruction, mediastinitis, thrombophlebitis of the jugular vein, cranial nerve dysfunction, cervical osteomyelitis, meningitis, and death [2].

Even though several authors have reported successful non-operative management in selected groups, there is still no standardized way of selecting patients who are suitable for non-operative therapy and those requiring surgical drainage [2–5]. Selection of optimal treatment for each patient in the early stages of a DNI is important for avoiding serious and potentially fatal complications and a prolonged hospital stay.

It is widely known that decisions made on physical examination alone regarding whether a neck swelling in a patient with DNI is healthy, cellulitic, or abscessed vary between examiners and have limited accuracy (63%) [6]. A number of diagnostic imaging tools for DNI have been developed recently. Computed tomography (CT) is one of the most useful methods for detecting if the lesion includes an abscess, although CT scans may be false-positive and neck explorations are occasionally negative. Laboratory studies, including complete blood count, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), neutrophil to lymphocyte (NL) ratio, and culture for bacterial growth may aid selection of an appropriate therapeutic strategy [7,8].

Mindful of the old adages about DNIs, such as “if in doubt explore” and “never let the sun go down on undrained pus” [9], we undertook this case-control study with the aim of identifying if there are any simple and objective laboratory or radiologic variables that could predict deep neck space abscesses guaranteed to be surgically drained successfully, and thereby minimize unnecessary neck exploration in patients with DNI.

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2. Materials and methods

2.1. Subjects

Ninety-seven consecutive patients were diagnosed with DNI in our clinic between March 2013 and June 2015. DNI was diagnosed based on presenting symptoms and signs seen on contrast-enhanced CT of the neck (soft tissue swelling, enhancement of involved muscles, obliterated fat planes, a hypodense area, peripheral rim enhancement, and irregularity [scalloping] of the wall of the collection). The inclusion criteria were presence of a DNI and complete laboratory, radiologic, and operative or medical findings within 24 h allowing analysis and prediction of the need for incision and drainage (I & D). If the patient appeared unlikely to respond to intensive medical therapy within 24 h and to have a significant abscess in the opinion of a head and neck surgeon, immediate I & D was undertaken. In the remaining patients, if the abscess worsened after medical therapy, delayed surgery was performed within 72 h after reevaluation of a CT neck scan. Depending on the operative findings, regardless of whether surgery was immediate or delayed, each patient was allocated to a drained group (i.e., I & D of purulent fluid was confirmed) or a non-drained group (i.e., exploration of cellulitis was negative). Patients with a DNI that healed without I & D were included in the non-drained group.

Ethical approval to conduct the study was obtained from the Institutional Review Board at the Hospital. All procedures were conducted in accordance with the Declaration of Helsinki, and this research is being reported in line with STROBE guidelines. The need for informed consent was waived because of the retrospective nature of this study and lack of any intervention or identified personal information.

The work has been reported in line with the STROCSS criteria [26].

2.2. Data collection

Data on patient demographics (age, sex), laboratory test results (white cell count, neutrophil percentage, absolute neutrophil count, CRP, ESR, NL ratio, fever), CT scan findings, whether or not I & D was performed, operative findings, and the results of treatment were collected by chart review. The CT findings for each patient were evaluated by a head and neck surgeon, who calculated the dimensions and minimum Hounsfield units for the hypodense area (abscess pocket, see Supplementary Fig. 1) and noted gas formation and marginal rim enhancement on the collecting wall. The operative findings were reviewed to determine if purulent fluid was drained or not. The demographic data and details of investigations performed were compared between the drained and non-drained groups (Table 1).

2.3. Statistical analysis

Differences in clinical parameters between the groups were tested for statistical significance using the Student *t*-test. Pearson's chi-square tests were used to evaluate associations. Multivariate logistic regression models were used to identify predictors in the group of patients that needed I & D after adjusting for confounding factors. A receiver-operating characteristic (ROC) curve was used to identify the cut-off value determining the need for I & D. The cut-off value was chosen to maximize Youden's index (sensitivity + specificity - 1). The statistical analysis was performed using SPSS version 18.0 software (IBM Corp., Armonk, NY, USA). The DeLong test was performed for two correlated ROC curves to estimate the predictive value of the score. $P < 0.05$ was considered to be statistically significant.

2.4. Derivation of clinical prediction score prompting I & D

After selection of cut-off values that maximized both sensitivity and specificity, the continuous variables were subdivided into low-risk and high-risk. Univariate regression analysis was used to identify significant variables for inclusion in stepwise multiple logistic regression analysis. Variables in the stepwise analysis with $P < 0.05$ were considered to be statistically significant. A regression coefficient was obtained for each significant variable. Coefficients and variables that were significant in univariate and stepwise analysis are listed in Table 2. Points for the clinical prediction score were assigned by doubling the value of the regression coefficients from the stepwise logistic regression and rounding off each number to the nearest one (Table 3). We then created a cut-off point to classify patients according to whether they did or did not have a successfully drained abscess.

Table 1
Comparison of demographic and medical data in patients with deep neck infection who did and did not undergo drainage.

Variable	Non-drained group (n = 58)	Drained group (n = 39)	P-value
Age (years)	37.8 ± 22.9	41.5 ± 26.2	0.47
Male sex, n (%)	32 (55.2)	27 (69.2)	0.16
Fever (°C)	37.4 ± 0.9	37.1 ± 0.7	0.18
CT findings in hypodense area			
Peripheral rim enhancement (presence), n (%)	31 (53.4)	32 (82.1)	0.00*
Minimum Hounsfield units	24.6 ± 13.4	18.0 ± 14.3	0.02*
Hypodense area (cm^2)	3.33 ± 2.0	3.86 ± 1.84	0.19
Gas forming (presence), n (%)	3 (5.2)	5 (12.8)	0.17
Laboratory findings			
C-reactive protein (mg/L)	79.4 ± 71.1	128.2 ± 99.6	0.01*
Erythrocyte sedimentation rate (mm/hr)	50.0 ± 27.0	67.7 ± 24.8	0.00*
White blood cell count ($10^3/\mu L$)	14.11 ± 7.8	17.4 ± 7.0	0.03*
Neutrophils (%)	76.1 ± 13.4	80.5 ± 11.7	0.10
Absolute neutrophil count ($10^3/\mu L$)	10,637.9 ± 5982.9	18,522.4 ± 30,707.0.	0.06
Neutrophil to lymphocyte ratio	6.69 ± 4.6	11.0 ± 9.6	0.01*

Abbreviation: CT, computed tomography. * Significant at $P < 0.05$.

Table 2
Logistic regression analyses to identify factors associated with necessary surgical drainage in patients with deep neck infection.

Variable	Univariate regression	P-value	Multivariate regression	OR
	OR		Coefficient	
Age (> 52.5 years)	1.96	0.134		
Male sex	1.828	0.166		
Fever (> 36.5 °C)	1.823	0.342		
Rim enhancement	3.982	0.005*	1.841	6.304
Hounsfield units (> 10.5)	1.056	0.929		
Hypodense area (> 2.45 cm^2)	4.167	0.006*		
Gas formation	2.696	0.193		
CRP (> 41.25 mg/L)	4.80	0.004*	1.317	3.732
ESR (> 56.5 mm/h)	5.00	0.000*	1.480	4.394
WBC (> 13.65, $10^3/\mu L$)	3.424	0.005*		
Neutrophil (> 82.15%)	2.435	0.036		
ANC (> 10,325.5, $10^3/\mu L$)	3.874	0.002*		
NL ratio (> 8.02)	3.556	0.004*	1.621	5.057

Abbreviations: ANC, absolute neutrophil count; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; NL ratio, neutrophil to lymphocyte ratio; OR, odds ratio; WBC, white blood cell count. * Significant at $P < 0.05$.

Table 3
Variables determining the clinical prediction score for necessary surgical drainage and points assigned. The final cut-off value of the score was estimated. If three of four variables meet the criteria, surgical drainage can be recommended for the patient.

Variables	Points
Positive peripheral rim enhancement	3
CRP (> 41.25 mg/L)	2
ESR (> 56.5 mm/h)	2
NL ratio (> 8.02)	3
Total	10
Estimated cut-off value	6.5

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; NL ratio, neutrophil to lymphocyte ratio.

2.5. Validation of clinical prediction score

A prospective study would be needed to estimate the predictive ability of this clinical prediction score, but could not be performed for ethical reasons. We compared the dimensions of the area under the curve (AUC) between the ROC curve of the score and others using the DeLong test (Fig. 1). The P-value was adjusted using Bonferroni correction. Following the statistical analysis, the clinical prediction score was calculated for 32 patients with DNI (the validation set) between July 2015 and October 2016. The surgical outcomes in these patients were determined and the reliability of the score was evaluated.

3. Results

3.1. Patient demographics

Ninety-seven patients suspicious for DNI who had complete laboratory tests, operative or medical findings, and CT results available within 24 h were enrolled. Thirty-nine patients were included in the drained group (immediate or delayed I & D) and 58 in the non-drained group (negative exploration or conservative medical treatment). Complications of DNI, including tracheotomy (n = 32), sepsis (n = 6), mediastinitis (n = 2), and pneumonia (n = 2), were successfully treated. The decision was taken to perform delayed I & D in seven patients after a mean 2.3 days of medical treatment. Four (9.3%) of the 43 surgically treated patients had a negative exploration showing cellulitis with necrotic debris. The demographic and clinical characteristics of the patient population are shown in Table 1. Categorical variables and differences between the groups were compared using the chi-square test. Continuous variables and differences between the groups were compared using the *t*-test. The values for six variables (peripheral rim enhancement, minimum Hounsfield units, CRP, ESR, white blood cell count, NL ratio) were significantly different between the two groups.

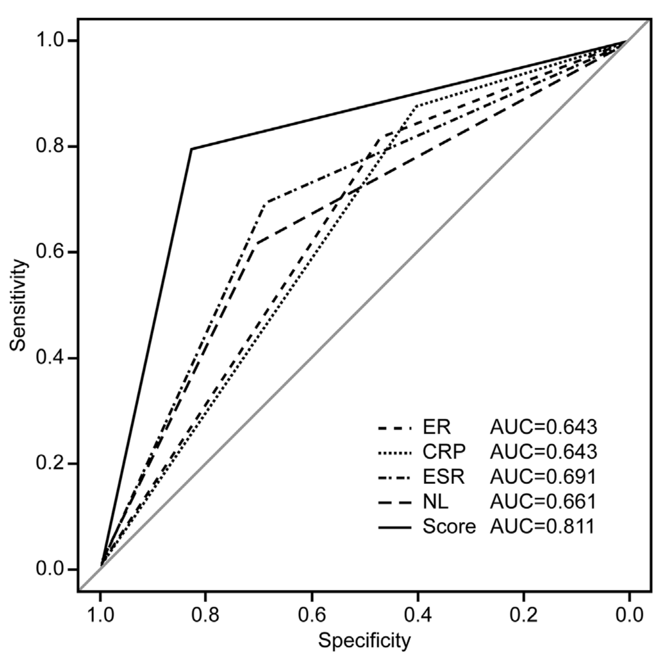

Fig. 1. Receiver operating characteristic curve of the clinical prediction score for successful surgical drainage in deep neck infection when compared with other parameters. Abbreviations: AUC, area under the curve; CRP, C-reactive protein; ER, enhanced rim on CT; ESR, erythrocyte sedimentation rate; NL, neutrophil to lymphocyte ratio.

3.2. Derivation of clinical prediction score prompting I & D

The factors considered were changed to categorical variables using the cut-off values. In univariate regression analysis, rim enhancement, a hypodense area, CRP, ESR, white cell count, absolute neutrophil count, and the NL ratio were identified as significant variables. In stepwise multiple logistic regression, the final significant factors were rim enhancement, CRP, ESR, and the NL ratio (Table 2). The clinical prediction score prompting I & D was obtained using weighted regression coefficients. The final cut-off value for the clinical prediction score prompting surgical drainage was 6.5. This binary classification test score was measured for performance [10] and found to have a sensitivity of 79.5%, specificity of 82.8%, accuracy of 81.4%, a false-positive rate of 20.5%, a false-negative rate of 17.2%, a positive predictive rate of 75.6%, and a negative predictive rate of 85.7%.

3.3. Validation of clinical prediction score prompting I & D

The clinical score had a significantly wider AUC than the other parameters selected in multivariate logistic regression analysis except for ESR. The estimated AUC for the clinical score was 0.811 (95% confidence interval [CI] 0.73–0.89) and those for the other parameters, i.e., rim enhancement, CRP, ESR, and the NL ratio, were 0.643 (95% CI 0.55–0.73), 0.643 (95% CI 0.56–0.73), 0.691 (95% CI 0.60–0.79), and 0.661 (95% CI 0.56–0.76), respectively; on Bonferroni correction, the adjusted P-values were 0.011, 0.001, 0.088, and 0.04, respectively.

The clinical prediction score was then tested retrospectively in a further 32 patients (validation set; drained [n = 19]/non-drained [n = 13]) who had been treated more recently using the same protocol. The mean age in this group was 50.4 ± 23.7 years and the proportion of male patients was 68.7% (n = 22). The score was found to have a sensitivity of 73.7%, specificity of 92.3%, accuracy of 87.5%, a false-positive rate of 7.6%, a false-negative rate of 26.3%, a positive predictive rate of 93.3%, and a negative predictive rate of 70.5%.

4. Discussion

Selection of appropriate treatment in the early stages of a DNI is important. Most DNIs can be treated successfully with antibiotics or drainage of pus, and there is some evidence that intravenous antibiotics alone can be effective for DNI [4]. However, delayed drainage or incorrect choice of antibiotic may have life-threatening consequences [11]. Despite the availability of antibiotics, surgical drainage still has an important role in the management of DNI. Therefore, detection of cases that need prompt surgical drainage is essential.

Recent advances in diagnostic imaging, such as CT and ultrasonography, mean that more information about the need for drainage is available than ever before. Decision-making based on clinical assessment, laboratory results, and radiologic findings is known to be the most accurate. Surgeons need to be able to predict that I & D will be successful preoperatively to avoid unnecessary surgery, especially in patients with DNI and severe comorbidity in whom there is the risk of a premature incision disrupting the normal physiologic barrier and spreading infection [12]. In this study, we divided patients with DNI into a drained group and a non-drained group, and derived a clinical prediction score using a combination of factors. This scoring system was confirmed to predict the need for drainage.

Several studies have compared preoperative findings with intraoperative findings in patients with DNI. Miller et al. [13] reported that a combination of clinical examination and interpretation of contrast-enhanced CT has the strongest sensitivity (95%) and specificity (80%) for diagnosing DNI. They used the gold standard, i.e., presence of pus at the time of surgery or spontaneous drainage within 24 h of CT, to determine the final outcome. They prospectively evaluated the outcome with reference to the preoperative clinical examination and CT findings, and found that fever, leukocytosis, floor-of-mouth induration or elevation, and tongue elevation, but not trismus and dysphagia, were significant clinical predictors of a drainable collection. They emphasized the possibility of underdiagnosing the presence of a drainable collection when relying solely on clinical examination, which had a higher specificity (73%) than sensitivity (55%). In contrast, CT had a higher sensitivity (95%) than specificity (53%) and they recommended determination of the extent of DNI via a combination of considerations. Discrepancies between preoperative CT interpretation and intraoperative findings in the initial stages have been reported, and these can be marked for retropharyngeal and parapharyngeal infections in children [14–16].

The present study identified several factors that could distinguish between abscesses needing I & D and small abscesses or cellulitis that can be treated medically. In multivariate logistic regression analysis, performed to identify potential predictors in the drained group, peripheral rim enhancement of a hypodense area on CT scan, increased CRP (> 41.25 mg/L), increased ESR (> 56.5 mm/h), and an NL ratio > 8.02 were candidates for derivation of a clinical prediction score. Diagnosis of an abscess is mainly based on physical examination, and takes into account a chronic induration, a well-circumscribed localization, fluctuance on palpation, presence of pus, and anaerobic bacteria. However, clinical examination alone cannot grade the abscess objectively or be used as the basis for a decision to proceed to surgery. Preoperative documentation describing the presence of abscess only on physical examination could not be obtained in this retrospective study. Therefore, findings on clinical examination were excluded from our clinical prediction score model.

The radiologic findings considered in this study were typical for a diagnosis of a DNI-related abscess, but only rim enhancement was selected for the scoring system. Some researchers have reported that the volume of the hypodense area (> 2 mL) is more important than ring enhancement when trying to predict an abscess [13,16]. Smith et al. [17] discussed the importance of decision-making on clinical grounds but also reported a high negative exploration rate (25%) for predicting deep neck space abscesses using CT scans when considering differences in Hounsfield units. The Hounsfield unit is the standardized attenuation coefficient used for CT scans. Our results showed that the size of the hypodense area (cut-off 2.45 cm^2) and Hounsfield unit measurements (cut-off 10.5) were significantly different between the two groups, but these were not selected for the multiple logistic regression model.

The benefit of laboratory findings in the differential diagnosis of abscess is usually cited to be prevention of life-threatening complications, such as respiratory distress, mediastinitis, and sepsis [18]. Wang et al. [19] demonstrated that a high CRP (> 100 mg/L) is only a significant predisposing factor for complicated DNI. In our study, ESR (> 56.5 mm/h) and CRP (> 41.25 mg/L) levels were different between the two groups and were selected for our clinical prediction score model. Further, we demonstrated the usefulness of the NL ratio (cut-off 8.2) in predicting drainable collections in patients with DNI. The NL ratio has been reported to be a potential marker of inflammation in both cardiac disorders and non-cardiac conditions such as cancer [20,21]. Baglam et al. [22] reported the predictive value of the NL ratio (cut-off 5.4) for DNI secondary to acute bacterial tonsillitis.

In this study, we attempted to derive a clinical prediction score using simple criteria to determine rapidly if a patient with a DNI has a drainable collection in need of I & D. It should be noted that this scoring system is not designed to predict the long-term outcome of a DNI. This type of scoring system is already well known in emergency departments. Examples include the Glasgow Coma Scale and Apgar score, which have gained consensus despite inter-rater disagreement [23,24]. To enhance the inter-rater reliability, we attempted to change the numeric parameters to categorical parameters, and simple radiologic findings were used to distinguish a drainable abscess from cellulitis. The final scoring system can be simplified further by considering that if at least three of the four parameters are met (therefore, meeting the 6.5 cut-off value), surgical drainage is indicated; this simplification facilitates utilization of this system for frontline clinicians. Well et al. [25] derived a similarly simple clinical model to categorize the probability of pulmonary embolism from the known associated factors such as tachycardia and compared their scoring model with the D-dimer result. Our clinical prediction score was superior to that in a previous report with regard to specificity (92.3% vs. clinical examination; 73% vs. CT; 53% vs. drainable collection > 2 mL on CT; 80% vs. CT plus clinical examination 80%) with acceptable sensitivity (73.7%) [13].

This study would have been improved by verifying our scoring system in other hospitals with a larger number of subjects and having multiple observers to measure the radiologic findings. This would decrease the inter-observer discrepancy and identify any overestimation using this scoring system. The gold standard decided by the surgeon would be improved if it was measured by a blinded observer, and although imperfect, we added patients who were treated medically to reduce verification bias on the part of the surgeon who designed this study. In this study, we followed the indication of surgery based on our decision from clinical examination and CT, but a group (n = 4, 9.3%) with negative exploration was found. We expect that more conservative therapy, such as guided needle aspiration or antibiotic therapy alone for cellulitis, would have been better for three of the patients who had a low score. The final validation of this score showed decreased sensitivity (from 79.5% to 73.7%) when compared with the result from the study population; this demonstrates a potential limitation of this scoring system since it has a lower sensitivity compared to that of 95% for the combination of clinical examination and interpretation of contrast-enhanced CT [13]. However, our scoring system was better than clinical examination alone (55%) [13], and considering its high specificity (92.3%), our clinical prediction score would be helpful for patients with a surgical indication, but an unclear physical examination. We suggest this scoring system can exclude less severe DNI patients with only CT data and laboratory results, and therefore minimize unnecessary neck exploration for high risk patients, which may be especially valuable for less experienced junior surgeons.

5. Conclusions

Surgeons often hesitate to perform I & D in patients with DNI because of uncertainty as to whether the abscess is drainable or not, the issue of surgical morbidity, and the option of conservative treatment. Retrospective analysis and derivation of our simple clinical prediction score suggest that CRP, ESR, the NL ratio, and rim enhancement on CT are significant predictors of the need for drainage. Although validation in prospective clinical trials are warranted, we expect this easy scoring system will be helpful in avoiding unnecessary drainage when deciding whether or not to proceed to I & D.

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Ethical approval

Ethical approval to conduct the study was obtained from the Institutional Review Board at Cheonan Hospital, Soonchunhyang University College of Medicine, Cheonan, Republic of Korea (2016-08-017).

Conflicts of interest

The authors have no conflicts of interest to declare.

Research registration unique identifying number (UIN)

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Author contribution

1. Study design: MJB, JHP.
2. Data collection: MJB, JYJ, JWK, KNP, SWL.
3. Data analysis: MJB, JHP.
4. Writing: MJB, JHP.
5. Supervision: JYJ, JWK, KNP, SWL, YWK, JHP.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ijsu.2018.02.024.

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