Original Article

Blood loss in total *en bloc* spondylectomy for primary spinal bone tumours: a comparison of estimated blood loss versus actual blood loss in a single centre over 10 years

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Background: Total en bloc spondylectomy (TES) is a widely accepted surgical technique for primary spinal bone tumours but is frequently accompanied by substantial peri-operative blood loss. Prior studies have reported estimated blood loss (EBL) can reach up to 3,200 mL. The aim of this study is to estimate the blood loss during TES procedures performed in the last ten years at our tertiary referral centre and compare EBL with actual blood loss (ABL).

Methods: We performed a retrospective review of all cases managed surgically with TES referred to our centre between 2005 and 2015. We recorded the oncological characteristics of each tumour and surgical management in terms of resection margins, operative duration and instrumentation. Data relating to peri-operative blood loss was also recorded including an estimation of total blood loss, the use of cell salvage where applicable and transfusion rates.

Results: A total of 21 patients were found to meet our inclusion criteria. There were 11 men and 10 women, with a median age of 40 years. The mean total ABL was 3,310 mL. Total operation time ranged from 6.53 to 19.7 h. Compared to ABL, in 59% of cases EBL had been underestimated by an average of 78% by volume. The EBL of the remaining 41% cases had been overestimated by 43%. This was not statistically significant (P=0.373). Cell salvage was used in 62% patients with a mean blood loss of 2,845 mL (884–4,939 mL) and transfusion of 3.8 units (0–12 units) versus 4,069 mL (297–8,335 mL) and 9.3 units (0–18 units) in those not managed with cell salvage. There was no significant difference in ABL between the cell salvage and non-cell salvage groups.

Conclusions: We report one of the largest case series in TES for primary bone tumours. EBL is not a reliable predictor for ABL. A large blood loss should be anticipated and use of cell salvage is recommended.

Keywords: Total en bloc spondylectomy (TES); blood loss; spinal tumours; oncology

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Introduction

The resection of primary bone tumours of the spine presents many surgical challenges, often due to the proximity of the tumour to the neural structures and great vessels (1). Traditionally, piecemeal resection of the tumour was performed but this often resulted in incomplete resection and high risk of local recurrence. However, *en bloc* removal of the diseased vertebrae (spondylectomy) has become a widely accepted surgical technique allowing for the entire vertebral compartment to be excised (2-4). This procedure aims to achieve clear tumour margins which significantly reduces the rate of local recurrence (1). Complete resection is commonly achieved using a one or two-staged procedure, starting with resection of the posterior elements followed by resection of the anterior elements. A single all-posterior or double posteroanterior approach are commonly used, although a double anteroposterior approach can also be used (5). Modifications to these approaches are dependent on the level of tumour, the ability to achieve satisfactory safe margins and the ease of resection (5). Spinal column reconstruction is commonly completed utilising an expandable cage or bone graft. Total en bloc spondylectomy (TES) procedure is indicated for patients with primary spinal bone tumours (benign and malignant), including but not limited to; chondrosarcoma, chordoma, giant cell tumour (GCT), Ewing's sarcoma, osteosarcoma, and osteoblastoma. Some patients with spinal metastases may also be considered for TES (1).

The proximity of the spinal column to major vessels makes TES a high-risk procedure for blood loss (6). The long surgical duration (average 14 hours) and the need for multi-step operations increase this risk further (5). Tomita *et al.* (2) recorded an average blood loss of 2,300 mL during TES for a single thoracic vertebra, whereas Sciubba *et al.* (6) estimated a median blood loss of 3,200 mL for TES operations for differing pathologies throughout the spinal column including the lumbar and sacral spine. Consequently, a median estimated blood loss (EBL) of 3,200 mL was used at the comparative standard for this study. This study aimed to assess the EBL during TES performed in the last 10 years at a single tertiary spinal centre in the United Kingdom and compare it with actual blood loss (ABL). We present the following article in accordance with the STROBE reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-22-27/rc).

Methods

We performed a retrospective review of our prospectively held spinal oncology database for all TES cases performed at our centre between 2005 and 2015. Inclusion criteria were: (I) patients with primary spinal bone tumours (malignant and benign); (II) patients undergoing TES (as decided in our specialist multi-disciplinary meeting). Patient data including age at operation and gender were collected from clinical notes. The following oncological characteristics for each tumour were recorded: type, size and vertebral level/s. Surgical variables were also recorded, including levels instrumented and levels resected, operation duration and the number of operation stages. Use of a cell salvage machine during the operation was also recorded [Sorin Xtra® Autotransfusion System (ATS), LivaNova, London, UK]. EBL per TES operation was obtained from anaesthetic notes or the World Health Organisation (WHO) post-operative checklist report. In cases of multiple-stage operations, EBL values and operation duration times were summed to produce totals for the whole TES procedure. The number of perioperative blood transfusions was also recorded, as well as any post-operative blood transfusions given prior to the first post-operative haemoglobin measurement taken.

Calculation of ABL

In cases where EBL had not been recorded, ABL was calculated using the pre-operative patient body weight, pre- and post-operative haemoglobin, and peri-operative transfusion rates. The Gross (7) formula was used to calculate the ABL as described below:

$$Gross's\ ABL = \left(blood\ volume \times \left[\left(Hb_i - Hb_f\right)/Hb_m\right]\right) \quad [1]$$

Hb_i = initial haemoglobin measurement, defined as the last haemoglobin measurement taken pre-operatively.

Hb_f = final haemoglobin measurement, defined as the first haemoglobin measurement taken post-operatively.

Hb_m = mean of the initial and final haemoglobin measurement.

Blood volume (mL/kg) was calculated using the following formula:

$$For\ males: blood\ volume = body\ weight\left(kg\right) \times 70\ mL \quad [2]$$

$$For\ females: blood\ volume = body\ weight\,(kg) \times 65\ mL \quad [3]$$

To account for any increase in haemoglobin levels as a result of peri- and post-operative blood transfusions prior to the first post-operative haemoglobin measurement, the number of red blood cells transfused per case were calculated using the following formula and added to the ABL value.

As per Trust protocol, blood transfusion was indicated where serum haemoglobin levels were less than 8 g/dL unless the patient had significant cardiac morbidity, where transfusion was indicated for serum haemoglobin levels less than 9 g/dL.

$$Total\ number\ of\ red\ blood\ cells\ transfused = 220\,(red\ blood\ cells/unit) \times number\ of\ units\ transfused \quad [4]$$

Our final formula for ABL:

$$ABL = \left(blood\ volume \times \left[\left(Hb_i - Hb_f\right)/Hb_m\right]\right) + total\ number\ of\ red\ blood\ cells\ transfused \quad [5]$$

Statistical analysis

Data are presented as median values with interquartile ranges. Kruskall-Wallis test was performed for all oncological and surgical variables. Dunn's post-hoc test was applied if the initial analysis showed significant differences in blood loss. For patient characteristics, use of cell salvage and analysis of EBL *vs.* ABL, an unpaired *t*-test was performed. P values less than 0.05 were considered statistically significant. Statistical analysis was performed using Prism (Version 8.0.0 for Windows, GraphPad Software, San Diego, California, USA).

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional board of the Royal Orthopaedic Hospital, Birmingham, UK (No. 17-037) and individual consent for this retrospective analysis was waived.

Results

Demographics

Thirty-three patients underwent TES without intralesional pediculotomy for primary bone tumours of the spine at our centre between 2005 and 2015. Twelve patients were excluded due to incomplete data records (n=6), postoperative mortality and inaccessible notes (n=2) and anaesthetic notes located at an alternative trust (n=8). Median age at operation was 40 years (IQR, 25–48 years). Tumour size ranged from 0.126 to 1,377 cm^3. Total operative duration ranged from 392 to 1,180 minutes. The median number of total peri- and postoperative blood transfusions per patient was 5 (IQR, 2–7). Cell salvage was used in 62% patients with a mean blood loss of 2,845 mL (884–4,939 mL) and mean transfusion volume of 3.8 units (0–12 units) respectively, versus 4,069 mL (297–8,335 mL) and 9.3 units (0–18 units) in those not managed with cell salvage. Further demographic details can be found in *Table 1*.

EBL vs. ABL

A record of EBL was found in 81% of cases (17/21). For the remaining cases, ABL was calculated using the modified technique described above. To ensure that ABL was an appropriate measure of EBL, ABL was also calculated for all cases where EBL had been recorded (*Figure 1*). Compared to ABL, in 59% of cases EBL had been underestimated by an average of 78% by volume (IQR, 38–101%). The EBL of the remaining 41% cases had been overestimated by 43% by volume (IQR, 33–52%). Despite the differences found between ABL and EBL, this was not statistically significant (P=0.373). Due to the disparity between EBL and ABL and to standardise our analysis, ABL was used for the remainder of the study.

ABL

The median total ABL for complete TES operations was 3,041 mL (IQR, 1,630–4,335 mL) with a mean ABL of 3,310 mL. The ABL in 48% of our cases was found to exceed the standard of 3,200 mL by an average of 1,976 mL. In the remaining 52% of cases, ABL was found to be lower than the standard by an average of 1,585 mL. There was no significant difference in ABL between any of the patient age groups: <30 (n=7), 30–39 (n=4), 40–49 (n=6), 50–59 (n=3) and ≥60 (n=2) (*Figure 2A*). The gender of the patient also did not influence ABL (*Figure 2B*). No significant difference in ABL between tumour types, sizes or number of operation stages was found (*Figure 2C-2E*). A trend towards significance was found for number of levels instrumented, with a P value of 0.067 (*Figure 3A*). Despite that there

Table 1 Demographic data for patient undergoing TES

Clinical variable	Patient characteristics	Number [%] (n=21)
Gender	Male	11 [52]
	Female	10 [48]
Site	Cervical spine	2 [10]
	Thoracic spine	7 [33]
	Lumbar spine	8 [38]
	Sacral spine	4 [19]
Number of procedure stages	One	8 [38]
	Two	11 [52]
	Three	2 [10]
Histology	Chondrosarcoma	9 [42]
	Chordoma	7 [33]
	Ewing's sarcoma	2 [10]
	Osteoblastoma	1 [5]
	Giant cell tumour of bone	1 [5]
	Other	1 [5]
Number of vertebral levels removed	One	9 [42]
	Two	7 [33]
	Three	3 [15]
	Four or more	2 [10]
Number of vertebral levels instrumented	One	2 [10]
	Two	1 [5]
	Three	6 [28]
	Four or more	12 [57]
Pre-operative embolisation	Yes	0 [0]
	No	21 [100]

TES, total en bloc spondylectomy.

was a significant difference in ABL across the vertebral location of the tumour (P=0.0102) as shown in (*Figure 3B*), *post-hoc* tests showed no significance when each group was compared to the other. Operation duration also showed a significant difference in ABL with longer operative duration being associated with increased blood loss (P=0.03) (*Figure 3C*). However, no significant differences were found during post-hoc tests. There was no significant difference in ABL between operations that used cell salvage compared to those that did not (*Figure 3D*).

Discussion

Statement of principle findings

Our study has demonstrated that EBL is an unreliable indicator of ABL in the context of TES for primary spinal bone tumours. Median ABL was 3,041 mL and required transfusion in all cases (autologous or allogenic). Use of cell salvage was associated with a lower average transfusion volume compared to those managed without (3.8 *vs.* 9.3 units respectively) but this failed to reach statistical significance (P=0.5775). ABL was not overtly influenced by tumour histology, size or by number of operative stages. A trend towards significance was seen with increasing number of vertebral levels instrumented (P=0.067), vertebral location (P=0.010) and operative duration (P=0.03).

Clinical relevance

Spondylectomy was first reported by Lièvre *et al.* in 1968 as a two-stage technique following a GCT resection from the 4th lumbar vertebrae (8). This technique has been adopted and modified by several authors over the past decades (9-11). Although TES is recognised to be a fairly aggressive surgical approach, it has become the gold standard of treatment for spinal tumours given the growing body of evidence supporting the influence of good local control on survival rates with potentially curative outcomes (12,13).

Patients with primary spinal bone tumours are at risk of significant blood loss due to tumour-related factors such as proximity or invasion of vascular structures or hypervascularity of the tumour tissue itself (14). Several measures have been described in the literature to minimise blood loss including preoperative embolisation of segmental and feeding arteries above and below the tumour, perioperative administration of antifibrinolytic drugs such as tranexamic acid, intraoperative controlled hypotension, meticulous hemostasis, the use of hemostatic agents, and the use of intra-operative cell salvage (1,15,16). Despite our unit employing many of these measures to limit blood loss, our study found that a typical patient undergoing TES loses a median ABL of 3,041 mL and there was no statistically significant difference in transfusion rates when using cell salvage. Although the ABL demonstrated in this study is less than the standard of 3,200 mL described in Sciubba

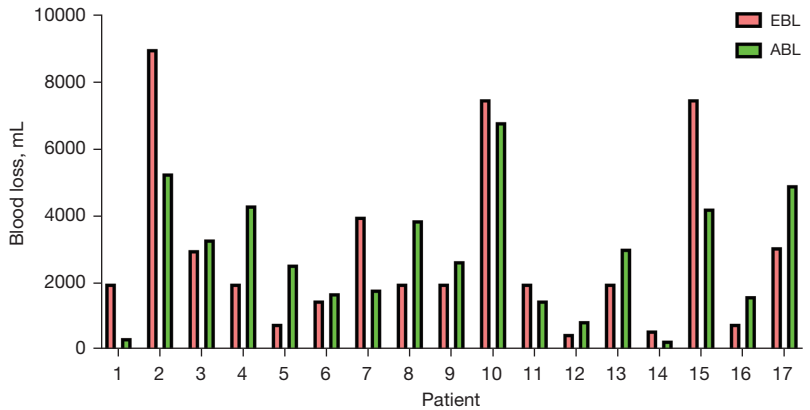

Figure 1 EBL from operative records *vs.* ABL calculated using the gross formula. EBL, estimated blood loss; ABL, actual blood loss.

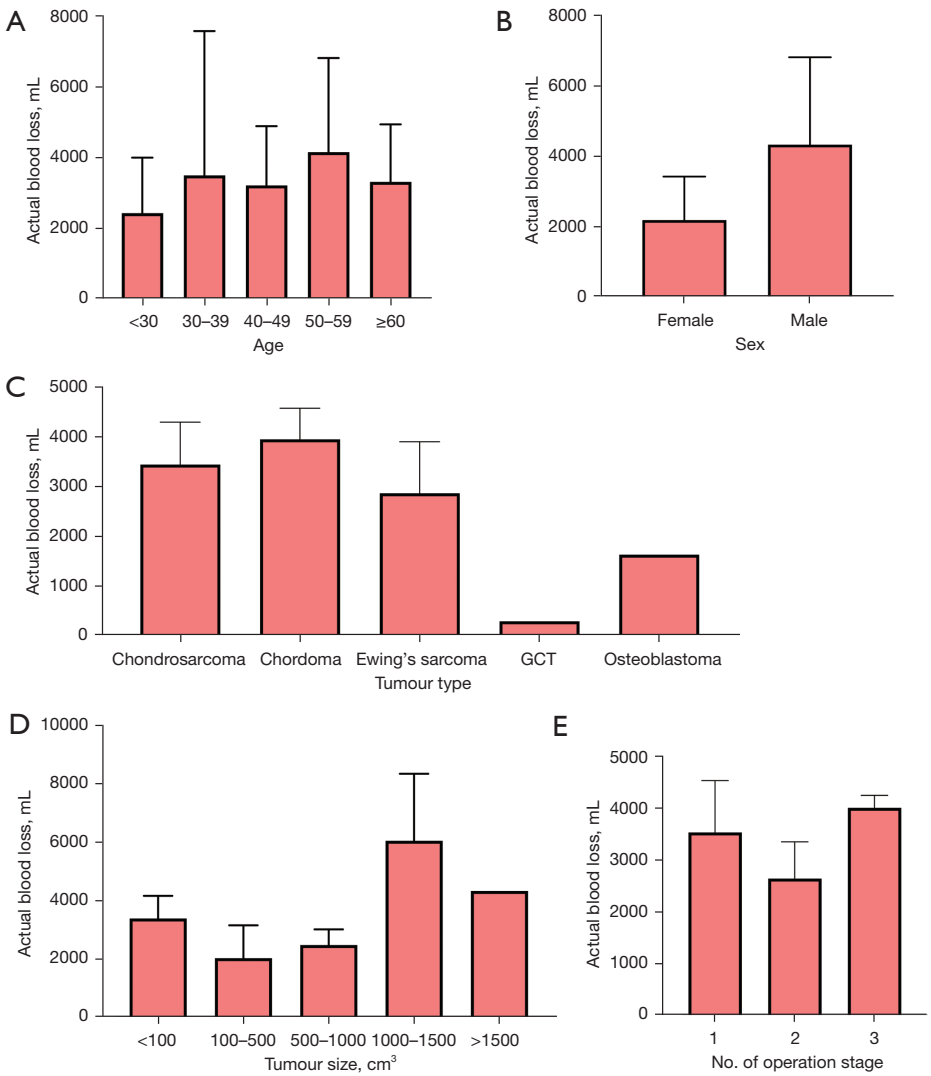

Figure 2 ABL by variable. (A) Age; (B) sex; (C) tumour type; (D) tumour size; (E) number of operation stages. GCT, giant cell tumour; ABL, actual blood loss.

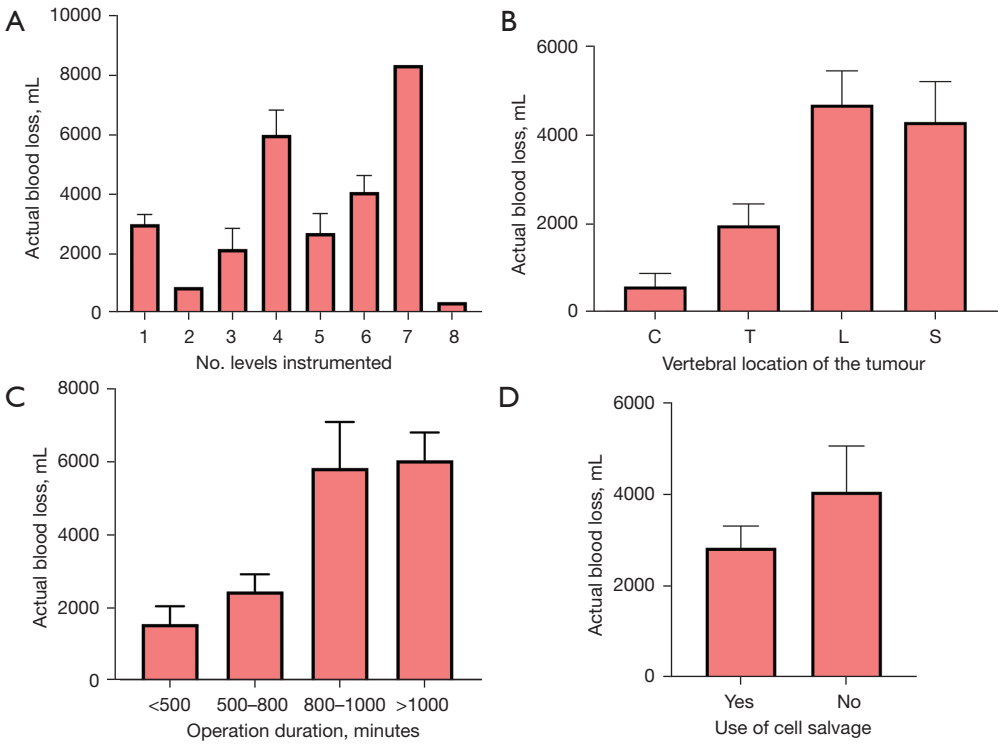

Figure 3 ABL by variable. (A) Number of vertebral levels instrumented; (B) vertebral location of tumour; (C) operative duration; (D) use of cell salvage. C, cervical; T, thoracic; L, lumbar; S, sacral; ABL, actual blood loss.

et al. (6), it remains significant and we must remain mindful of the large potential blood loss in the pre-operative planning and consenting stages (6).

Intra-operative blood loss is usually replenished by allogenic blood transfusion (ABT) (17). Despite the safety of ABT having improved, the risk of post-operative infection, immune-mediated complication and stimulation of the tumour still exist (17,18). This has promoted efforts to reduce dependence on ABT and find other alternatives such as intra-operative autotransfusion of salvaged blood (19,20). Autotransfusion of salvaged blood has long been proven to reduce the requirement for ABT in non-oncological elective surgeries (21-23). However, concerns exist that transfusion of salvaged blood might re-transfuse malignant cells and cause subsequent metastasis (24,25). Despite this, there is emerging evidence supporting the use of intraoperative cell salvage for major spinal surgery in deformity, oncology and degenerative settings (16,20,26-30) and it remains standard practice to use cell salvage in our unit for TES procedures based on this growing body of evidence.

Choi and colleagues (29) demonstrated in their study that intra-operative cell salvage reduced the need for ABT in 81 patients undergoing long level posterior spinal segmental instrumented fusion for spinal deformity correction. In our series cell salvage was used in 62% patients with a mean blood loss and transfusion of 2,845 mL and 3.8 units respectively, versus 4,069 mL and 9.3 units in those not managed with cell salvage. Although there was no statistically significant difference in ABL between operations that used a cell salvage compared to those that did not (P=0.5775), we concluded that the use of cell salvage has decreased the need for ABT and it was associated with a lower blood loss. Furthermore, the use of cell salvage anecdotally doesn't appear to have had an adverse effect on survival and we would recommend its use based on the consensus of published literature (16,20,29).

Prior to the start of this study, we anticipated a significant increase in blood loss for tumours located in the lumbar region (31), long operation duration and with increasing number of vertebral levels instrumented. We noticed a trend towards our predictions however, significance levels were not reached when groups were compared to one another.

This could be due to the low number of cases included in this series due to its rare occurrence. As we continue to refine TES techniques in order to reduce the major risks, it is likely that more will be carried out and significant differences in blood loss for differing variables will be seen. This study found that EBL was not consistently recorded for all cases and was not an accurate measure of ABL. Although EBL and ABL were not significantly different, we recommend that ABL is used as a measure of blood loss as it reduces any variations that may be caused by operator interpretation.

Limitations

This study has several limitations. The study was retrospective in nature, which carries the risk of information bias and it was performed in a single centre with a relatively small sample size. This may have resulted in the statistical significance of our findings being undermined. The small sample size may also affect the generalisability of our results to the wider spinal tumour population, especially those managed similarly in a tertiary centre. Furthermore, EBL was not uniformly recorded and was measured by different staff members and was thus not standardised. Additionally, not all confounding factors were considered and survival/local recurrence/distant metastasis data is missing.

Despite the recognized limitations, this study reports one of the largest case series in TES for primary bone spinal tumours. Further prospective studies of a large sample size (including a multi-centre review) could reveal any trends in blood loss and the impact of routine use of intraoperative cell saver system in major spinal tumour surgery. We also anticipated that there would be no difference in survival, local recurrence and distant metastasis rates where cell salvage was and was not used—since cell salvage does not determine survival and the study was not randomised any effect demonstrated would be an observation, not a proven outcome.

Conclusions

TES operations still are associated with a major risk of blood loss; pre-operative measures and operative techniques must be refined in order to reduce the risk. In this study, EBL was shown to be an unreliable indicator of blood loss and the use of ABL reduces any variations that may be caused by operator interpretation. A large blood loss should be anticipated and the use of cell salvage should be considered.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jss.amegroups.com/article/view/10.21037/jss-22-27/rc

Data Sharing Statement: Available at https://jss.amegroups.com/article/view/10.21037/jss-22-27/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jss.amegroups.com/article/view/10.21037/jss-22-27/coif). MG reports having received support from DePuy Snythes to attend their own Expert Level 'Complications' Meeting in April 2022. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics board of the Royal Orthopaedic Hospital, Birmingham, UK (No. 17-037) and individual consent for this retrospective analysis was waived.

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