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Health Risks Associated with Crude Oil Spill Exposure

Mark A. D'Andrea, MD, G. Kesava Reddy, PhD, MHA

University Cancer and Diagnostic Centers, Houston, Texas.

ABSTRACT

BACKGROUND: Human exposure to crude oil spills is associated with multiple adverse health effects including hematopoietic, hepatic, renal, and pulmonary abnormalities. The purpose of this study was to assess the hematological and liver function indices among the subjects participating in the Gulf oil spill cleanup operations in comparison with the standardized normal range reference values.

METHODS: Using medical charts, clinical data (including white blood cell [WBC] count, platelet count, hemoglobin, hematocrit, blood urea nitrogen [BUN] creatinine, alkaline phosphatase [ALP], aspartate amino transferase [AST], alanine amino transferase [ALT], and urinary phenol) were gathered for the subjects who were exposed to the Gulf oil spill and analyzed.

RESULTS: A total of 117 subjects exposed to the oil spill were included. Over 77% of subjects had WBC counts in the mid range (6-10 × 10^3 per μL), while none of the subjects had the upper limit of the normal range (11 × 10^3 per μL). A similar pattern was seen in the platelet counts and BUN levels among the oil spill-exposed subjects. Conversely, over 70% of the subjects had creatinine levels toward the upper limit of the normal range and 23% of subjects had creatinine levels above the upper limit of the normal range (>1.3 mg per dL). Similarly, hemoglobin and hematocrit levels were toward the upper limit of normal in more than two thirds of the subjects. AST and ALT levels above the upper limit of normal range (>40 IU per L) were seen in 15% and 31% of subjects, respectively. Over 80% of subjects had urinary phenol levels higher than detectable levels (2 mg per L).

CONCLUSION: The results of this study support our earlier study findings in which we found that people who participated in oil spill cleanup activities are at risk of developing alterations in hematological profile and liver function.

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KEYWORDS: Chemical exposure; Health impact; Hematological toxicity; Hepatotoxicity; Urinary phenol

Crude oil spills are tragic environmental disasters that can affect human health through exposure to inherent toxic chemicals including para-phenols and volatile benzene.[1,2] Human exposure to crude oil spills can lead to deleterious effects on many biological systems, including changes in the hematologic, hepatic, respiratory, renal, and neurological functions.[3,4] Recently, we investigated the adverse health effects of the Deepwater Horizon oil spill exposure in subjects participating in oil spill cleanup activities along the coast of Louisiana.[5] Specifically, we assessed the hematologic and hepatic markers in a cohort of oil spill cleanup workers and the clinical findings were compared with a group of unexposed (control) subjects. The findings of the study revealed significant differences in blood profiles and liver enzymes between the oil spill exposed and unexposed cohorts, indicating health risks among subjects who participated in the oil spill cleanup operation.[5]

Because the most reported clinical biomarker findings for both hematological and liver function indices fell within the normal range values for exposed and unexposed groups, concerns were raised about the study design and interpretation of the study findings.[6,7] This prompted us to carry out an additional analysis of clinical data that has been recently reported.[5] In the analysis, we assessed the blood profile and liver function data in comparison with the standard normal range values among the subjects who participated in the

Gulf oil spill cleanup operation. The resultant outcomes are summarized to further facilitate the understanding of the health impact of oil spill exposure among subjects observed previously.

MATERIALS AND METHODS

Subjects

The details of identification of the subjects exposed to the oil spill were described in our previous manuscript.[5] Briefly, the subjects exposed to the oil spill were identified as participants in the oil spill cleanup activities along the coast of Louisiana. Medical charts were reviewed by an experienced physician. Clinical data such as white blood cell (WBC) counts, platelet counts, hemoglobin, hematocrit, blood urea nitrogen (BUN), creatinine, alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) levels were collected and evaluated. In addition, data on urinary phenol was also assessed as a benzene metabolite in the oil spill-exposed subjects.

Analysis

As shown in Table 1, the average reference values were derived from the normal range values for various indices of hematological and liver functions and the clinical data were processed. In addition, the normal range values were divided into various categories and the clinical data were analyzed. The variables included WBC and platelet counts, as well as the levels of hemoglobin, hematocrit, creatinine, BUN, ALP, AST, ALT, and urinary phenol.

Table 1 Normal Range Values for Various Indices

Parameter	Normal Range Value	Optimal (Average) Normal Value
WBC ($\times 10^3$ per μ L)	4.0-10.5	7.25
Platelets ($\times 10^3$ per μL)	140-415	276
Hemoglobin (g per dL)	12.6-17.7	15
Hematocrit (%)	37.5-51.0	44
BUN (mg per dL)	6-24	15
Creatinine (mg per dL)	0.76-1.27	1.0
ALP (IU per L)	25-150	88
AST (IU per L)	0-40	20
ALT (IU per L)	0-40	20
Beta-2 macroglobulin (mg per L)	0.6-2.4	1.5
Urinary phenol (mg per L)	0-trace	2

ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; BUN = blood urea nitrogen; IU per L = International Units per liter; WBC = White blood cells.

CLINICAL SIGNIFICANCE

- Crude oil spills are tragic environmental disasters that have high potential to affect human health.

- The results of this study indicate that humans exposed to crude oil spill have a risk of developing hepatic or blood-related disorders.

- The hematological and hepatic alterations include altered platelet counts, serum creatinine, urinary phenol, and liver function enzymes.

RESULTS

This study included a total of 117 subjects who were involved in the cleanup operations of the oil spill. Of the 117 subjects, 104 (89%) were male and 13 (11%) were female. The median age of the subjects was 34.0 (18-63) years.

The findings presented in the Figure (panel A) indicate the outcomes of WBC, platelet counts, and BUN levels assessment in the oil spill-exposed subjects. Based on the normal range values, WBC count was averaged at 7.2 ($\times 10^3$ per μL) and the total number of subjects who had WBC counts below and above the average value of normal range was determined. Of the 117 subjects, 71 (61%) had WBC counts below the average value of normal range. Similarly, 79 (68%) of the subjects had platelet counts below the average value of normal range when 276 ($\times 10^3$ per μL) was considered as the average value of normal range. Assessment of BUN levels also indicated that 68% of the subjects had below the average value of normal range when the average value of normal range of BUN levels was considered to be at 15 mg per dL.

The results shown in the Figure (panel B) depict the outcomes of serum creatinine, hemoglobin, hematocrit, and urinary phenol levels assessment in the oil spill-exposed subjects. Based on the normal range values, serum creatinine levels averaged 1.0 mg per dL and the total number of subjects who had creatinine levels above and below the average value of normal range was determined. Of the 117 subjects, 57 (49%) had serum creatinine levels above the average. Similarly, 76 (65%) of the subjects had hemoglobin levels above the average when 15 mg per dL was considered as the average value of normal range. Assessment of hematocrit levels indicated that 65% of the subjects had levels above the average value of normal range when the average value of normal range of hematocrit levels was considered to be at 44 mg per dL. Similarly, 93 (79%) of the subjects had urinary phenol levels above the average value of the normal range when 2.0 mg per L was considered as the average value of the normal range.

The findings presented in the Figure (panel C) reveal the outcomes of liver function enzymes such as AST, ALT, and ALP levels assessment in the serum of oil spill-exposed subjects. Based on the normal range values, AST and ALT levels in the serum were averaged at 20 IU per L, and the total number of subjects who had AST or ALT levels above and below the average was determined. Of the 117 subjects, 84 (72%) had serum AST levels above the average of the normal range. Similarly, 89 (76%) subjects had serum
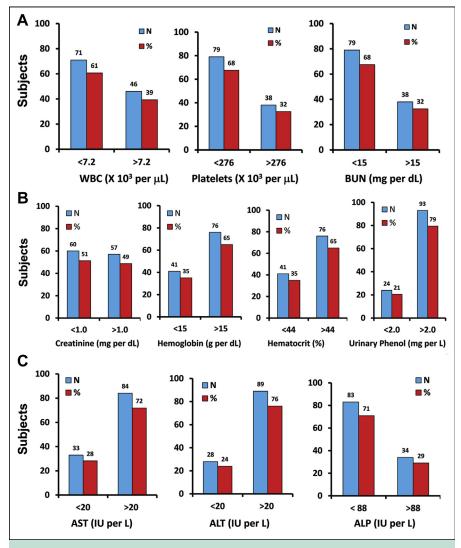
Figure Changes in biological markers in subjects involved in the Gulf oil spill cleanup operation. (**A**) Changes in white blood cell (WBC) counts, platelet counts, and blood urea nitrogen (BUN) levels. (**B**) Changes in serum creatinine, hemoglobin, hematocrit, and urinary phenol levels. (**C**) Changes in liver function enzymes such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) levels.

ALT levels above the average of the normal range. Conversely, only 29% of the subjects experienced serum ALP levels above the average when 88 IU per L was considered as the average value of the normal range.

The outcomes were compared with the normal range reference values that were grouped into lower-, middle-, and upper-limit ranges in addition to the above-normal range. The results presented in **Tables 2** and **3** indicate the outcomes on

Table 2 Blood Profile with Various Indices in Subjects (n =117) Involved in Oil Spill Cleanup Activity

WBC (× 10³ per µL)		Platelets (× 10³ per µL)		BUN (mg per dL)	
Count	n	Count	n	Level	n
<5.0	14 (12.0%)	<200	23 (19.7%)	<11.0	33 (28.2%)
6.0-<8.0	50 (42.7%)	200-<250	36 (30.8%)	11.0-<15.0	46 (39.3%)
8.0-<10.0	40 (34.2%)	250-<300	35 (29.9%)	15.0-<20.0	32 (27.4%)
10.0 -<11.0	13 (11.1%)	300-<400	23 (19.7%)	20.0-<24.0	6 (5.1%)
≥11.0	0 (0.0%)	≥400	0 (0.0%)	≥24.0	0 (0.0%)

BUN = blood urea nitrogen; WBC = white blood cells.

Table 3   Blood Profile and Urinary Phenol in Subjects (n =117) Involved in Oil Spill Cleanup Activity

Creatinine (mg per dL)		Hemoglobin (g per dL)		Hematocrit (%)		Urinary Phenol (mg per L)	
Level	n	Level	n	Level	n	Level	n
<0.80	11 (9.4%)	<13.0	21 (17.9%)	<40	11 (9.4%)	0	10 (8.5%)
0.8-<0.9	22 (18.8%)	13.0-<15.0	20 (17.1%)	40-<45	42 (35.9%)	<2.0	13 (11.0%)
0.9-<1.0	27 (23.1%)	15.0-<16.0	60 (51.3%)	45-<50	56 (47.9%)	2.0-<5.0	38 (32.5%)
1.0-<1.3	30 (25.6%)	≥16.0	16 (13.7%)	≥50	8 (6.8%)	5.0-<10.0	31 (26.5%)
≥1.3	27 (23.1%)	N/A	N/A	N/A	N/A	≥10.0	25 (21.4%)

blood profiles and urinary phenol levels in subjects involved in the oil spill cleanup operations. Over 77% of the subjects had WBC counts in the mid range (6-10 × 10^3 per μL), while none of the subjects had upper limits of the normal range (11 × 10^3 per μL). A similar pattern was seen in the platelet counts and BUN levels among the oil spill-exposed subjects. However, nearly one third of subjects had BUN levels less than the lower limit (11 mg per dL) of the normal range. Conversely, over 70% of the subjects had creatinine levels toward the upper limit of the normal range and 23% of subjects had creatinine levels above the upper limits of the normal range (>1.3 mg per dL, Table 3). Similarly, hemoglobin levels were raised toward the upper limit of the normal range (>15 g per dL) in more than two thirds of the subjects. Hematocrit levels were also in the upper limit of the normal range in over 50% of the subjects. Over 80% of the subjects had urinary phenol levels more than detectable levels (2 mg per L) and 21% of the subjects had urinary phenol levels >10 mg per L (Table 3).

The findings presented in Table 4 show the levels of the hepatic enzymes such as AST, ALT, and ALP in the serum of the subjects involved in oil spill cleanup operations. AST levels above the normal range (>40 IU per L) were seen in approximately 15% of the subjects. Similarly, ALT levels above the normal range (>40 IU per L) values were seen in approximately 31% of the subjects. Conversely, none of the subjects had ALP levels above the normal range (>150 IU per L) values.

DISCUSSION

In a previous study, we evaluated the health effects of the Deepwater Horizon oil spill exposure in a cohort of oil spill cleanup workers.[5] The study found that the blood profiles and hepatic enzymes were significantly altered in subjects exposed to the oil spill compared with the unexposed subjects. Because the standard reference values have a wide range for the indices, a follow-up study was undertaken to assess the outcomes with respect to the standard reference values. Specifically, the outcomes were compared with the average value of the normal range values of each parameter. Further, the outcomes were compared with the normal range reference values that were grouped into lower-, middle-, and upper-limit ranges in addition to the above-normal range.

The findings of the study indicate that subjects who participated in the oil spill cleanup operations experienced changes in their blood profiles and hepatic enzymes. The study findings indicated that about 60%-70% of subjects exposed to the oil spill had WBC and platelet counts as well as BUN levels below the average normal reference value. Conversely, 50%-65% of subjects exposed to the oil spill had creatinine, hemoglobin, and hematocrit levels above the average normal reference value. Urinary phenol levels were also found to be above the average normal reference value in approximately 80% of oil spill-exposed subjects. Similarly, liver function enzymes such as AST and ALT were found to be above the average normal reference value in over 70% of oil spill-exposed subjects. Thus, these findings support our earlier study findings in which we found that subjects who participated in the oil spill cleanup activity are at an increased risk of developing hematological and liver function abnormalities.[5]

The abnormality of various biological markers in subjects who are involved in oil spill cleanup operations is further evidenced by the changes in various indices including creatinine, hemoglobin, hematocrit, liver function

Table 4   Liver Function Enzymes in the Serum of Subjects (n =117) Involved in Oil Spill Cleanup Activity

AST (IU per L)		ALT (IU per L)		ALP (IU per L)	
Level	n	Level	n	Level	n
<20	33 (28.2%)	<20	28 (23 .9%)	<60	27 (23.1%)
20-<30	49 (41.9%)	20-<30	38 (32.5%)	60-<80	48 (41.0%)
30-<40	18 (15.4%)	30-<40	15 (12.8%)	80-<100	23 (19.7%)
≥40	17 (14.5%)	≥40	36 (30.8%)	≥100	19 (16.2%)

ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase.

enzymes (AST and ALT), and urinary phenol. The results show that over 15% of subjects experienced some of these biomarker indices over the upper limit of the normal reference range, and over 50% of subjects had the indices toward the upper limit.

Overall, the findings indicate that the subjects were not affected uniformly by the oil spill exposure. This could be due to the differences in duration and intensity of exposure, protective equipment, preexisting health conditions, use of medications, and the differential immunity to the toxic chemicals of the oil spill. In addition, subjects' age may have contributed to the variations in findings observed in the study. Nonetheless, the findings of the study suggest that subjects involved in oil spill cleanup operation are at an increased risk of developing health-related sequelae and support our earlier findings reported in the previous article.[5]

ACKNOWLEDGMENT

References

1. Solomon GM, Janssen S. Health effects of the Gulf oil spill. *JAMA*. 2010;304:1118-1119.
2. Merhi ZO. Gulf Coast oil disaster: impact on human reproduction. *Fertil Steril*. 2010;94:1575-1577.
3. Goldstein BD, Osofsky HJ, Lichtveld MY. The Gulf oil spill. *N Engl J Med*. 2011;364:1334-1348.
4. Diaz JH. The legacy of the Gulf oil spill: analyzing acute public health effects and predicting chronic ones in Louisiana. *Am J Disaster Med*. 2011;6:5-22.
5. D'Andrea MA, Reddy GK. Health consequences among subjects involved in Gulf oil spill clean-up activities. *Am J Med*. 2013;126:966-974.
6. Wickliffe JK, Wilson MJ, Lichtveld MY. Major Concerns About Study Design and Clinical Biomarker Interpretation. *Am J Med*. 2014;127(9):e21-e22.
7. Piacentino J, Silver S, Bernard B, DeBord DG, Funk R, Decker J. Study methodology prevents interpretation of findings in workers involved in Gulf oil spill cleanup activities. *Am J Med*. 2014;127(9):e25-e26.