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Study of injuries from the Chelyabinsk airburst event

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ABSTRACT

The ~20-m sized asteroid that entered the Earth's atmosphere at 19 km/s over the Chelyabinsk Region of Russia on February 15, 2013, broke and deposited ~500 kt of kinetic energy at 45–25 km altitude, causing an airburst strong enough to create widespread glass damage. The shockwave hit a densely populated area. More than a thousand people asked for medical assistance at hospitals. In this paper, we analyze the available information about how many and what type of injuries were sustained. We combine previously collected data from government reports and from phone and internet surveys shortly after the event with newly collected data from local hospitals. As expected, the percentage of injuries was highest near the asteroid trajectory, but surprisingly the type of injury (cuts or bruises) do not show dependence on the distance from the asteroid trajectory. Results are compared to asteroid impact risk assessment models. The results provide insight for first responders in future asteroid impacts and help to refine these models.

1. Introduction

The Chelyabinsk airburst event from February 15, 2013, demonstrated that asteroids as small as 20 m in diameter are able to cause widespread property damage and injuries. Over 1600 people asked for medical assistance at hospitals. This realization led to new efforts to better assess the risk of asteroid impacts (Rumpf et al., 2016; Motiwala et al., 2015; Mathias et al., 2017).

These risk assessments are critically dependent on the assumed consequences of asteroid impacts under a variety of circumstances. The risk depends on the kinetic energy of the asteroid, its size and speed, as well as the impact angle and material properties. The shock wave generated by the asteroid breakup and deceleration of fragments can reach the ground, creating structural damage and seismic waves. In addition, thermal and UV radiation can be strong enough to injure people, start fires, and even melt the ground in some cases. Impacts that reach the Earth's surface create a crater and eject material into the atmosphere (Collins et al., 2005; Nemtchinov et al., 2008).

In the more frequent small impacts, such as Chelyabinsk, the damaging effects of the shockwave and thermal radiation are the main hazards. Overpressure can harm humans by creating a harmful pressure differential between the organ internal pressure and ambient pressure. People can sustain lung damage, eardrum rupture, concussion, being rendered unconscious, etc. Strong winds can throw people against objects, or throw objects against people, resulting in cuts, bruises, bone fractures, and other internal and external injuries (Glasstone and Dolan, 1977). Thermal radiation can cause flash burns to the body, as well as indirect burns by igniting materials in a person's surroundings. Those burns can be of different levels of severity and nature, depending on the source and duration of radiation. In addition, retinal and conjunctival burns, temporal blinding, as well as heat sensations may arise due to thermal radiation.

Most risk assessments from airbursts follow the approach taken by the Impact Earth Calculator (Collins et al., 2005), which in turn relies on data collected in the aftermath of nuclear explosions (Glasstone and Dolan, 1977). However, there is no perfect analogy between a static point-source explosion (say from TNT or nuclear) and a distributed energy release as experienced, for example, during the Chelyabinsk asteroid impact (Popova et al., 2013). A better approach is to calculate the energy release based on hydrodynamical models of asteroid entry and disruption

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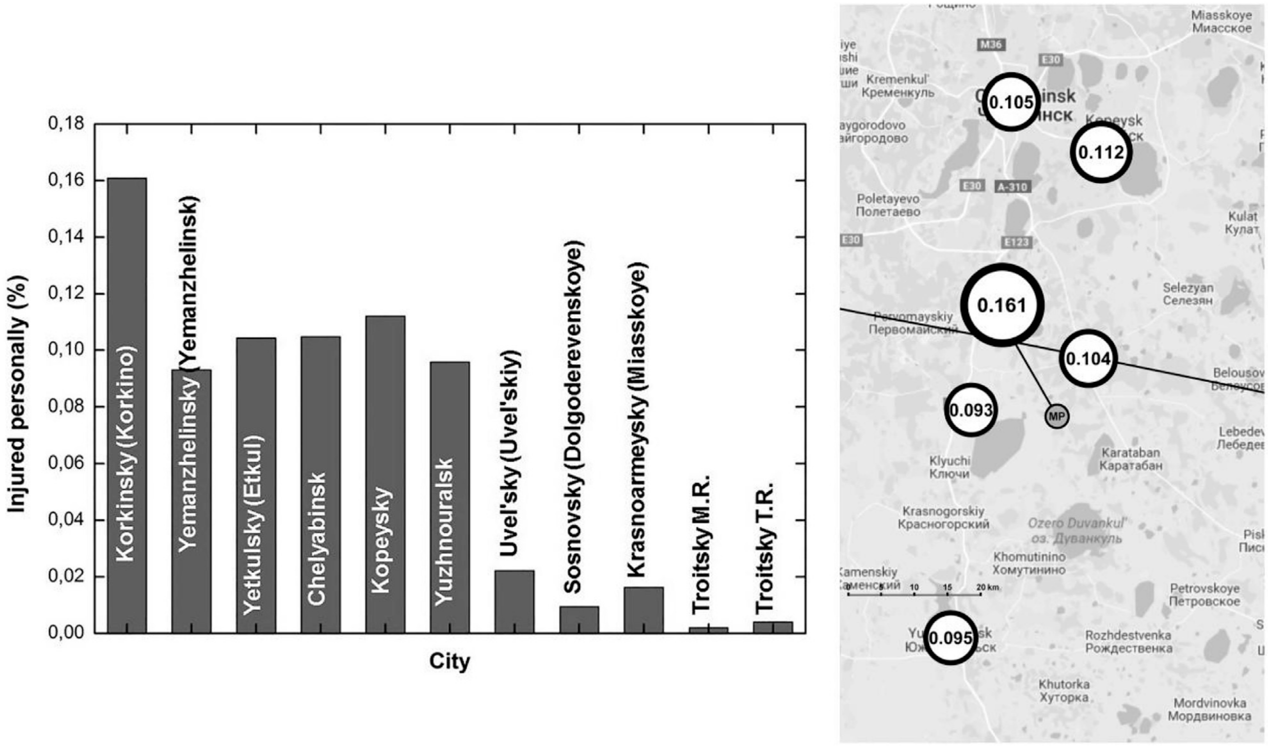

Fig. 1. Injuries by location based on official reports. Left: The percentage of injured people by municipal district. Right: The percentage of injured people relative to the meteoroid trajectory (black line) and point of main peak energy deposition (small grey circle, labeled "MP").

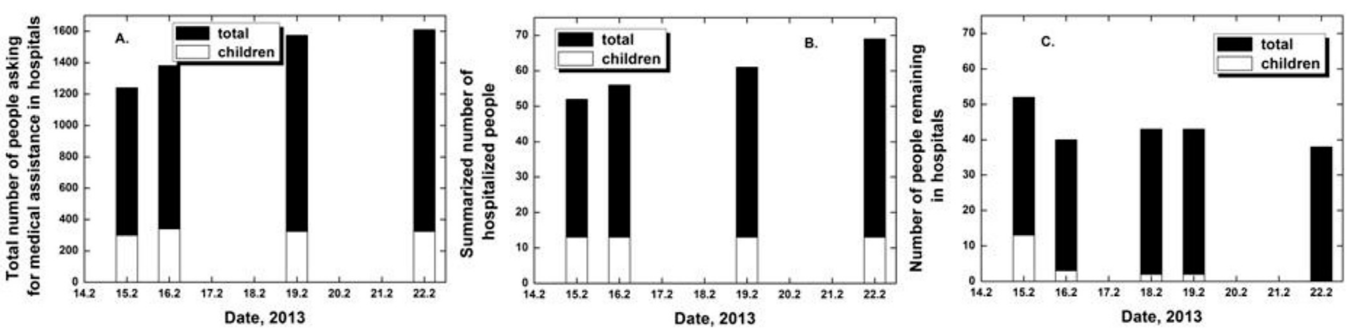

Fig. 2. Injuries reported as a function of time. (A) The number of people asking for medical assistance at different times following the airburst on February 15. The horizontal axis shows day in February 2013. Dates with no entries reflect an absence of data; (B) Number of hospitalized people; (C) Number of people remaining in hospitals.

(Shuvalov et al., 2013, 2016, 2017a,b).

In the same way, the action of thermal radiation in nuclear explosions studied by Glasstone and Dolan (1977) is often used in radiation hazard estimates (Rumpf et al., 2016; Mathias et al., 2017). However, the spectrum of radiation emitted during an asteroid impact may well differ from that emitted during a nuclear explosion.

All theoretical approaches to risk assessment need to be verified, and the Chelyabinsk event has provided the most comprehensive observational test to date. This paper presents new data on injuries from the Chelyabinsk airburst event, which complements and expands on previous data collected shortly after the event (Popova et al., 2013).

2. Data sources and methods

Much information about the level of damage in different municipal districts and some data on injuries can be found in an official report by the Russian Emergency Ministry (Akimov et al., 2015). Other information about injuries mainly comes from records obtained shortly after the event (Popova et al., 2013, 2014; Kartashova et al., 2014). Telephone interviews with some 500 residents of the Chelyabinsk area (0.04% of Chelyabinsk residents) were conducted by the Public Opinion Foundation (FOM) on 23 and 24 February 2013 (http://www.fom.ru). 1813 residents filled out a web-based query form, starting on February 21, 2013 (Popova et al., 2013), of which 1758 appear to be reliable. Finally, eyewitnesses were interviewed during a field study organized by the Russian Academy of Sciences 3–4 weeks after the event (Popova et al., 2013). Most of the respondents were from the city of Chelyabinsk, about 45 km from the main asteroid disruption event, but some were located closer and further from the trajectory (Kartashova et al., 2014).

In addition, we obtained some new data about injured people and the type of their injuries in recent years directly from the Krasnoarmeysk hospital, Etkul hospital, Korkino hospital and the Administration of Uvelsk district, who kindly responded to our letters.