Profound repolarization abnormalities after cylindrical battery ingestion: a case report

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Background Cardiac arrhythmias are a serious complication in patients admitted due to intoxication in suicidal attempts. Upon admission, detailed information about the specific kind of intoxication are frequently missing. The differential diagnoses of electrocardiogram (ECG) changes such as elevation of T-waves, prolongation of the QT-interval or elevation of ST-segments in this special subgroup of patients comprise drug-induced electrolyte disorders or direct toxic effects on cardiac excitation and repolarization.

Case summary In this clinical report of a 27-year-old male patient, we present a case of unusual ECG alterations mimicking ST-elevation, high amplitude, biphasic T-waves and prolongation of QT-interval. These changes of surface ECG were induced by ingestion of cylindrical batteries in a suicidal attempt and immediately normalized after removal of batteries by esophagogastroduodenoscopy.

Discussion There is limited literature describing changes in surface ECG in patients having ingested cylindrical batteries. We propose two hypotheses for the occurrence of these changes after ingestion of cylindrical batteries: (i) Cardiac movement within the perturbation field induced by the batteries causes electrical changes on a time scale of the heart rate which are above the threshold of the high pass filter. (ii) The batteries’ electrotonic potential affects the membrane currents of cardiac myocytes, not inducing an action potential but generating repolarization abnormalities. Individual factors, such as body constitution and localization of the batteries within the stomach, determine the interindividual characteristics of repolarization abnormalities.

Keywords T-wave-elevation • ST-elevation • U-waves • Cylindrical battery ingestion • Intoxication • Suicidal attempt • Case report

Learning points

• Ingestion of cylindrical batteries can lead to electrocardiogram (ECG) alterations consisting of pronounced interindividually different repolarization abnormalities. These changes immediately normalize after removal of batteries.

• Electrical perturbations need to be considered as a reason for ECG changes. Although generally rare, valid recognition of a respective situation can avoid invasive treatment and unnecessary diagnostic workup.
Introduction

Cardiac arrhythmias are a serious complication in patients admitted due to intoxication in suicidal attempts. Frequently, detailed information about the specific kind of intoxication are missing upon admission. In cases where electrocardiogram (ECG) changes are present, the differential diagnoses of the underlying intoxication can be narrowed down depending on the ECG abnormalities observed. Common ECG changes comprise bradycardia, supraventricular tachycardia, repolarization disorders, and ventricular arrhythmias. Repolarization abnormalities such as elevation of T-waves, ST-elevation, or prolongation of QT-interval are often associated with drug-induced electrolyte disorders and intoxication with antidepressants. Pronounced U-waves can be seen in hypokalaemia but have also been described in cases of lithium intoxication.

Timeline

| Time Description                  | Event                                                                 |
|-----------------------------------|----------------------------------------------------------------------|
| 2 h prior to presentation          | Ingestion of eight cylindrical batteries (size AA) in suicidal attempt|
| Upon presentation                 | Abdominal pain. Electrocardiogram (ECG) showing negative T-waves accompanied by giant positive U-waves in the inferior leads, ST-elevation in I and aVR and high amplitude negative U-waves in the precordial leads (V1–V5). |
| Upon presentation, Esophagogastro-duodenoscopy (EGD) | Removal of eight batteries (size AA) and one stainless-steel spoon handle. Mucosa with local sings of damage (erythema, oedema). Batteries heated due to high electrical current flow. |
| After EGD, 15 h after admission    | Complete normalization of ECG changes                                |

Case presentation

A 27-year-old male patient with a past medical history of depression was admitted to the emergency department having ingested an unspecified number of cylindrical batteries in a suicidal attempt. The patient denied use of any recreational drugs within the last 14 days. Apart from slight epigastric pain, physical examination remained unremarkable. An electrocardiogram (ECG) was performed immediately after arrival. The ECG revealed a biphasic, significantly prolonged repolarization period of the form (+/−) in leads I, aVR, aVL, V1–V5 and of the form (−/+ in leads II, III and aVF. To apply standard ECG nomenclature classifying these changes is difficult. If at all, ECG alterations resembled significantly pronounced biphasic T-waves. ST-segment elevation could be detected in leads I and aVR (Figure 1) and prolongation of QT-interval (QTc 591 ms) was present in all chest- and limb leads.

Serum levels of potassium, calcium, phosphorous, and magnesium as well as Troponin-T-levels were within normal range. According to the clinical guideline of the European Society of Gastroenterology and Endoscopy (ESGE), which generally recommends extraction of batteries from the stomach within 24 h mainly due to the risk of battery leakage inducing liquefaction necrosis, the patient underwent urgent esophagogastro-duodenoscopy (EGD). The patient was transferred to the intermediate care unit and eight batteries (size AA) as well as a stainless-steel spoon handle were removed successfully from the gastric fundus (Figure 2). The batteries’ temperature was significantly elevated and gastric mucosa showed localized oedema and erythema, implicating local mucosal damage due to high electrical current flow. The follow-up ECG, acquired after the removal of batteries, demonstrated normal T-waves, insignificant ST-elevation in leads I, II, aVF and a physiological QT-interval (QTc 405 ms) (Figure 3). The ECG changes observed were interpreted as ECG disturbances induced by the batteries’ electrical field and no further cardiac workup was performed. Abdominal radiographs obtained after removal of the batteries ruled out remaining foreign objects in the distal bowel segments which were not inspected by EGD. Showing no somatic disorders and no significant arrhythmias during continuous ECG-monitoring for 14 h after battery extraction the patient was transferred to a psychiatric clinic the next day. Since then, the patient has remained in a good physical state and has not been readmitted to our hospital.

Discussion

Heating of the batteries and localized mucosal damage are strong indicators of a significant flow of current between the batteries and surrounding gastric tissue. Batteries ingested in the stomach are in an electrolyte environment with high electrical conductivity. This enables ionic currents, induced by the superposition of electric dipole fields around the cylindrical batteries. Of note, these electrical phenomena occur in close proximity to the epicardial layer of the myocardium as well as precordial ECG-electrodes. We observed a biphasic, prolonged repolarization period of the form (+/−) in leads I, aVL, aVR, V1–V5 and of the form (−/+ in leads II, III and aVF (see above) translating into a prolonged QT-interval. Whereas ST-segment elevations can frequently be found in the context of acute cardiac ischaemia, prolongation of QT-interval may signify an increased risk of sudden cardiac death caused by ventricular arrhythmias. Apart from genetic long-QT-syndromes, a prolonged QT-interval can also be observed secondary to drugs compromising ventricular repolarization. As in this case, all repolarization abnormalities resolved immediately upon battery extraction, a causal interaction between battery ingestion and ECG abnormalities can be postulated. One explanation, linking battery ingestion and repolarization abnormalities, could be that the electric field, which, as generated by eight batteries, is of considerable magnitude, perturbs the field related to cardiac electrical activity. Following this hypothesis, one must keep in mind that the battery-related field is almost constant in time, at least on the time scale of cardiac activity. In principle, the high pass filter (>0.05 Hz) should eliminate voltage differences related to the battery field. However, cardiac movement within this perturbation field could induce electrical changes on a time scale of the heart rate which are above the threshold of the filter. To a minor portion, this could also hold for breathing excursions which explains the minor variations of the baseline.

Another explanation for the significant repolarization abnormalities derives from the electrotonic potential related to the battery.
Figure 1  Electrocardiogram upon arrival. 25 mm/s, 10 mm/mV, 100 Hz. Sinus rhythm, heart rate 89/min, normal axis, PR-interval 142 ms, P-waves with inferior axis, biphasic P-wave (+/−) in V1, QRS-duration 92 ms, R-wave transition V3/V4. Biphasic, significantly prolonged repolarization period of the form (+/−) in leads I, aVR, aVL, V1–V5 and of the form (−/+ in leads II, III and aVF. QT 486, QTc 591 ms.

Figure 2  Esophagogastroduodenoscopy-images. (A) Eight batteries (size AA) in the gastric fundus. (B) Gastric mucosa showing localized oedema and erythema. (C) Normal mucosa. (D) Batteries and spoon handle after removal.
field that could affect the membrane-conductance of cardiac myocytes. Although effects on membrane conductance induced by the electrotonic potential may not be potent enough to induce an action potential (AP), they may very well affect the slow varying membrane currents present during repolarization, generating repolarization abnormalities. The fact that the most pronounced alterations in surface ECG were seen in myocardial segments close to the stomach (inferior wall, right precordial but not lateral precordial leads) may further corroborate this hypothesis. Which hypothesis proofs to be right or whether both contribute to the ECG alterations cannot be answered from this case report (Figure 4).

Literature research revealed two case reports describing ECG-artefacts such as elevation of ST-segments and T-waves after ingestion of cylindrical batteries. In contrast to our case, Chang et al. describe an isoelectric baseline and no high amplitude, biphasic T-waves. The ECG published by Ordoobadi et al. shows biphasic prolongation of the repolarization period in leads V2 to V6 and slight ST-elevations in leads II, III, aVF as well as leads V4–V6. As our current case exhibits more pronounced and qualitatively different ECG changes, it can be assumed that a distinctive or even diagnostic ECG-pattern cannot be expected after battery ingestion. We argue that the differences of repolarization abnormalities are caused by differences of body constitution, the conductivity of intragastric fluid milieu and the type, number and localization of the batteries in the upper gastrointestinal (GI) tract. The remaining charge of the batteries as well as the timepoint after ingestion and possible series connection of the batteries may also play a role. We postulate that an asthenic habitus, high conductivity of intragastric fluid milieu, localization of the batteries in the gastric fundus close to the myocardium, recent ingestion of fully charged batteries and series connection of the batteries to be individual factors facilitating pronounced repolarization abnormalities. We furthermore argue that the designs (button battery, cylindrical batteries ranging from size AAAA to D, power pack batteries) as well as the voltage of batteries ingested (e.g. 1.5 V, 3.0 V and 9.0 V) impact the occurrence of ECG abnormalities. According to Ohm’s law, higher voltage causes an increase in current, inducing a stronger electrical field and hypothetically inducing more pronounced repolarization abnormalities. The likelihood of mucosa bridging the anode and cathode of a battery, allowing current to flow, appears higher in batteries with a larger design (e.g. cylindrical battery) than in small designs (e.g. button batteries). This hypothesis is supported by the fact that literature research revealed two cases of repolarization abnormalities after cylindrical battery ingestion, but no case of ECG abnormalities induced by button batteries ingestion.

Conclusion

Electrical perturbations need to be considered as a source of ECG changes. Recognition of a respective clinical situation can avoid
invasive treatment and unnecessary diagnostic workup. Ingestion of cylindrical batteries can lead to apparent repolarization abnormalities such as ST-segment elevation, the appearance of high amplitude, bi-phasic T-waves, and a massive prolongation of QT time. Electrocardiogram alterations immediately normalize after removal of batteries. We postulate that individual factors such as body constitution, type, and localization of the batteries within the stomach determine the interindividual characteristics of repolarization abnormalities. Apart from a perturbation of the cardiac electrical field detected by the ECG leading to artefacts, a direct impact of the electrotonic potential on cardiac membrane conductance can also not be excluded.

**Lead author biography**

After studies at the universities of Tübingen, Bristol and Brown Medical School, M. Huttelmaier graduated from Medical School at University of Tübingen in 2013 and completed training in internal medicine (University Hospital Wuerzburg) in 2019. Currently, he is working as a fellow of interventional electrophysiology in the department of internal medicine at the University Hospital of Wuerzburg.

**Supplementary material**

Supplementary material is available at European Heart Journal - Case Reports online.

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**Slide sets:** A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

**Consent:** The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

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