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Data-Driven Safety Messaging in Mining and Processing Facilities: Effects on Incident Rates and Reporting Behavior

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Abstract

This paper focuses on the impact of data-based safety messages and their relationship to processing and mining operations compared to the level of incidents and incident-reporting behavior. The archival safety histories of the many sites denote that three major elements of safety messaging are to be taken into consideration, that is, channel composition, message frequency, and readability. These results show that fewer incidents occurred through near-miss reporting regularly and with consistent communication schedules that improved the number of incidents multi-dimensionally through digital-offline methodologies. Readability was observed to play the key role; optimized messages, which were simplified and optimized using AI, improved understanding and interaction and risk patterns concealed in natural language processing. These results generalize the healthcare and manufacturing industry models of transplant safety climate and incident reporting in the mining sector and empirically demonstrate that AI-driven surveillance can potentially broadcast the messages of risk. The theoretical observations presuppose the propensity to introduce facility-wide platforms of communication and create a facility-specific playbook that would facilitate the personalization of delivering messages. Future research ought to be conducted on longitudinal AI-enabled experiments within high-risk industries in a bid to enhance cross-industry generalizability.

Keywords: Safety communication; Mining industry; Incident reporting; Message cadence; Channel mix, Readability; AI-driven risk management

1. Introduction

The aspect of occupational safety has been a significant subject in those industries whose risks of occurrence are high, such as mining and processing. These are the workplace conditions that can be linked to the risky working conditions that include the risks of being exposed to toxic substances and working with heavy machinery, and the most efficient safety practices are the key to the safety of employees (Barozai and Panezai, 2024). The history of exposure to airborne pollutants during the gold mining activities, including the activities that occurred in the past, reflects the immense magnitude of risks that the workers were exposed to when the safety measures were inadequate (Drake et al., 2001). In modern practice, emphasis has now been placed on reinforcing not only engineering controls but also the communication system to direct safe behavior on the ground.

Although the regulatory frameworks and organizational investments in safety programs are in place, the rates of incident in the mining and processing facilities are still alarming. The existence of a communication practices gap that is supposed to eliminate accidents is one of the main reasons for this trend. In the mining sector of Pakistan in particular, the results of the occupational health and safety management systems have been directly related to the intention of the

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employees to leave the companies, and the bad form of the communication practices among the participants has created higher risk exposure (Shaikh et al., 2025). Likewise, research about the near-miss cases in mining activities reveals that most workers do not report the dangers as early as possible, thereby exposing the shortcomings of the current reporting procedures (Zeqiri et al., 2022). Such loopholes represent the much-needed depiction of how convenient and compatible communication methods are with the behaviors of the workers.

Most of the facilities that have introduced incident reporting systems have been hampered by the culture and blaming perceptions, which have hampered their efficiency. An analysis of the settings in the hospitals has shown that the following workplace culture part in the attitudes with regard to reporting, with fear of consequences being a major suppressive factor (Alsobou et al. 2025). Other than culture, the design and usability of reporting instruments can also be important in this regard; in care environments, inconsistent design of systems has been linked to underreporting and incomplete documentation (Scott et al., 2024). All these findings mean that obstacles to effective reporting are multidimensional, which implies that they go beyond the field of policy compliance to include the way messages are framed, presented, and interpreted.

The proposed research helps to overcome the mentioned challenges by exploring the opportunities of optimizing data-driven safety communication in mining and processing facilities. The study measures the direct impact of three dimensions of communication—cadence, channel mix, and readability—on the occurrence of incidents and near-miss reporting.

Objectives

- To evaluate relationships between message cadence and safety outcomes.
- To assess the impact of channel mix on message uptake.
- To analyze readability levels and employee engagement with reporting.

2. Literature Review

2.1. Occupational Safety Communication in High-Risk Industries

The mining and processing plants have unique difficulties in effective safety communication. According to Barozai and Panezai (2024), geology and heavy machinery combined with environmental risks inherently make the sector highly risky, and clear and consistent communication becomes particularly important in this situation. According to Gendler et al. (2015), layered risk factors such as, but not limited to, equipment failures and human error mean that the communication systems need to be adjusted to the site conditions that are rapidly changing. Nevertheless, under well-laid-down procedures, there are always loopholes in the way messages are received and replied to.

The culture of safety is closely related to labor relations and compliance. Shaikh et al. (2025) find that the more accidents in the mines, the more their chance of having a poor reporting culture where the employees are scared of being blamed or they do not see much goodness in reporting near-misses in the mines. On the contrary, in the Kravchuk et al. (2024) commentary, it points out that turnover helps to put an end to communication chains, especially in cases where new employees do not know the existing procedures. Collectively, these studies demonstrate that there is more than the presence of reporting mechanisms to organizational context, which determines whether communication can be converted into safer behaviors.

These are generalized by cross-sector lessons. Alsobou et al. (2025) demonstrate that frequent and clear reminders increase adherence to safety protocols in healthcare, and Marks et al. (2014) indicate comparable positive effects in construction through the visual reminders and systematic repetition. However, mining is different because of the outdoor nature and dispersed work conditions, where noisy, dusty, and isolated work conditions restrict the channel of delivery of messages. This contrast is an indication of the fact that mining requires particular adaptations of communication strategies, which have been implemented in other high-risk industries.

2.2. Risk Communication Theories & Frameworks

There are theories of risk communication, which provide an explanation of safety messaging. Alfayez et al. (2025) emphasizethe importance of safety climate by showing that employees are more willing to report hazards when they believe that the management is concerned about the issue. Chaneliere et al. (2024) also demonstrate that it is not just form systems that determine whether near-miss reporting is normalized or suppressed since organizational culture has

the final say in this matter. These results are reminiscent of mining, in which hierarchies may or may not allow an open discussion of the risk.

Public health models such as the Crisis and Emergency Risk Communication (CERC) model have been adapted to industry. According to Scott et al. (2024), the principles of CERC can help increase the level of engagement from workforce engagement during safety campaigns: Clarity, timeliness, and empathy. In the same manner, Osorio et al. (2025) state that risk frameworks are the most useful ones when they are localized with messages specifically adapted to the literacy and cultural background of particular facilities. A combination of these works says that mining facilities might be better served by a systematic framework; however, they should reorganize to address hazards and workforce peculiarities.

Although models such as CERC assume the centralized power of communication, mining is more often founded on distributed supervision, with frontline managers giving essential information. Therefore, contrary to the situation with healthcare or government, where the centralized risk communication is predominant, the mining process requires the introduction of hybrid frameworks that would achieve the right balance between centralized standards and decentralized delivery. This is an indication of the need for risk framework validation in the sector and not wholesale acceptance.

2.3. Message Cadence & Repetition Effects (250 words)

Workers respond to safety messages in a very specific way depending upon the timing and the frequency of safety messages. Marks et al. (2014) note that having messages separated from one another between the different work shifts ensures greater memory and reduces message fatigue. On the same note, Tiwari and Malluri (2023) also indicate that making repetitive safety reminders increases compliance in performing protective behavior, but excessive repetition results in desensitization. These observations suggest that mining, which involves rotation shifts and long work cycles, requires managed cadence approaches.

Organizational-level reporting is coupled with cycles of response. Chaneliere et al. (2024) argue that the employees lose the motivation to give feedback whenever the messages reported contain delayed or delayed feedback. Comparatively, Gemeda (2025) concludes that in many cases, there is an observable managerial action resulting in the culture of trust and the strong reporting cultures. This resistance is based on two issues: the idea of cadence as a technical design issue and a conflict between management and the employees.

Notably, the evidence of the structured repetition of cycles is present in the healthcare and aviation sectors as well, but the mining side of this validation is not as solid. The active character of the dangers of mining, which are sudden cave-ins or gas leaks, demands even more adaptive strategies in cadence than the strategies that are exercised in a predictable surrounding. Therefore, repetition is effective at enhancing remembering in any line of business except in the mining business, where pacing ought to be relative enough to avoid overwhelming the worker but instead to enhance the alertness of the worker when working in a speedy environment.

2.4. Channel Mix in Safety Messaging

The effectiveness also depends on the channels of communication. Uwho, Asianuba Health 2025, the awareness of hazards within the mining and transportation industry: the effectiveness of multimodal systems (visual warnings, digital displays, and verbal instructions). Similarly, Nogueira et al. (2018) demonstrate that the channel redundancy guarantees the conveying of messages, even with the technical failures or in a noisy environment. This overlap is especially relevant in mines, where it is known that the single-channel communication slows down as a result of lack of connection or unsafe conditions.

Online communication is also being coupled with real-life communication. Digital tools enable it to be more efficient, but a face-to-face reinforcement must be made apparent, according to Ebert et al. (2025). Similar concerns have been seen in less than technology-savvy workers being made to feel out of the loop by Alsobou et al. (2025), as exclusively digital systems can pose a threat to the inclusiveness of any system. These results suggest that channel mix should be organized to fit the workforce demographics and environmental realities.

Nonetheless, while multimodal systems are promising, their expensive nature and technical sophistication may not be utilized at small mining operations. Therefore, the issue of efficiency of accessibility is an issue yet to be answered. According to the literature, it is hybrid solutions, where digital warnings are supported by personal reinforcement, which represent the most feasible channel within which the mining facilities aim to increase safety communications.

2.5. Readability and Comprehension

Engagement is directly related to the readability of safety messages and reporting tools. Osorio et al. (2025) show the plain language design boosts employees' involvement in the reporting of incidents. In the same way, Nasution and Ayuningtyas (2024) report that jargon in technical texts reduces familiarity with safety-critical industries, and it results in reduced error in responding behavior. These results are in sync with mining, where the proportion of workers with various levels of literacy is high, and readability is considered a huge issue.

New solutions are availed by new technologies. Antony and Xavier, 2025 The idea of using artificial intelligence-supported natural language processing (NLP) to simplify understandable and difficult-to-read reports is quite simple. The findings from Oluwagbade (2025) also point at the possibility of AI tools, which are able to render technical safety instructions into locally understandable dialects. These tools are, however, promising but are not yet well-validated in industrial environments, and this casts doubts on their accuracy and reliability given high-stakes environments.

It is prohibited to mine particular evidence. According to Medrado and Gibaut (2024), the research on readability in mining does not often consider channel optimization, but Zeqiri et al. (2022) affirm that the breakdown in communications is believed to be a significant factor of under-reporting. Moreover, Aror and Mupa (2025) discover that proper implementation of AI is taking shape in industrial safety, but this is not effectively tested, which is also echoed by Kalu-Mba et al. (2025), who caution that the implementation will bring about unintended risks. Collectively, these papers demonstrate that, although the readability and communication with AI have potential, mining needs to be customized and validated to guarantee that messages are truthful, inclusive, and efficient.

3. Methodology

The present study used a quantitative research, multi-facility study design to assess the role of safety communication strategies in affecting the frequency and reporting behaviors of incidence of mining and processing operations. The methodology was based on methodologies used in research to investigate the field of healthcare reporting, wherein the rate of communication, readability, and system design were statistically related to destination of reporting and reduction of error. (Alfayez et al., 2025) As demonstrated by Chanelere et al. (2024), multi-site analysis is comparative and offers a comprehensive view of organizational variables that may affect the reporting culture, which is most suitable in industries (including the mining industry) that are highly contractually varied.

The study environment was 5 mining and processing plants, which were located in the regions with different market conditions. Drake et al. (2001) observed that the use of heavy equipment, random geology, and predisposition to toxic wastes have always exposed the industry to a number of risks. Such risks were justified by Gendler et al. (2015), who underlined the increase of the risks of the work in the underground. Moreover, more recently, there are also innovations like bio-mining with which these facilities start to experiment, not harming the environment, but opening up completely new risks that need new approaches to safety and protection (Berghe et al., 2025). This blend of old and new risks was creating a topical environment for the role of communication strategies with respect to the outcome of safety to be established.

There were three dimensions of operationalization of the independent variables. The first measure was messaging cadence, which was measured by frequency of safety bulletins and reminders, and identified those facilities that used weekly cycles of messages versus those that used monthly communications. Previous research proves that an increase in frequency increases recall but threatens message fatigue (Marks et al., 2014; Tiwari and Malluri, 2023). Second, channel mix was coded based on the presence of a multimodal approach involving digital platforms, notice boards, and face-to-face briefings as indicated by Ebert et al. (2025) and Uwho and Asianuba (2025). Lastly, safety message readability was evaluated through the application of the Flesch-Kincaid scale and supplemented with the AI-based natural language processing tools to identify the presence of linguistic complexity and the use of technical jargon, as used in studies by Antony and Xavier (2025) and Oluwagbade (2025). The dependent outcomes were the near-miss reporting rates and the incident frequencies recorded. Zeqiri et al. (2022) found that near-miss reporting was a good predictor of safety climate in organizations, whereas Tsopa et al. (2025) noted that it predicts the prevention of major accidents.

A 12-month-long archival record was therefore acquired of the internal safety management systems of both facilities' sources of archival data. Secondary data consisted of safety bulletins, near-miss incidents, and incidents, in the same manner that archival data sets had been used to supply credible evidence concerning the effectiveness of communication used in the healthcare context (Nasution and Ayuningtyas, 2024; Alsobou et al., 2025). To achieve

comparability, the reports were categorized into standardized types of event type and communication format based on methodologies that had been presented in Medrado and Gibaut (2024).

Two stages of data analysis were made. The regression models were the initial method that was employed as the instrument that could evaluate the relationship between communication practices and the number of incidents, which is identical to the method that is adhered to in the process safety modeling techniques (Tiwari and Malluri, 2023). As a supporting point, natural language processing was utilized in calculating tendencies of readability of messages and assessment of linguistic adaptations in different facilities (Oluwagbade, 2025). This dynamism and combination of both statistical and computational processes provided the prospect of quantitative rigor as well as the qualitative richness of determining the effects of communication.

The study had good ethical protective measures. Incident reports were de-identified, and anonymized data were analyzed in a bid to confer confidentiality to the employees. Ethical measures were in accordance with the processes learned in the literature regarding patient safety reporting, where anonymity and confidentiality are vital in sustaining the quality of trust as well as fostering disclosure (Osorio et al., 2025). Published results included only facility-level aggregated data to prevent indirect identification of workers or single incidents.

4. Findings

4.1. Message Cadence

The facilities that had a higher rate of safety communications that mostly consisted of weekly bulletins together with the shift-start reminders reported a great increase in the near-miss reports compared to those with a monthly rate, as seen in the analysis. The outcome is comparable with the earlier research by Marks et al. (2014), who have already said that the regular partaking is associated with improved memory, as well as the emergence of a more proactive safety culture. Similarly, Tiwari and Malluri (2023) observed that repetitive presentation of process safety messages positively contributes to compliance with reporting expectations, particularly within a risky environment. The reporting in the sites of weekly cadence was enhanced nearly by 30% as a result of near-miss reporting in the mining and processing sites where researchers conducted their investigation.

However, the divergent data also had some evidence of diminishing returns. Those facilities that had attempted daily updates or excessive repetition hit a plateau, and some reported a reduction of reporting rates after several months. The surveys done later on after work revealed that workers experienced message fatigue, which was not different from Gemeda (2025), where they discovered a lack of continuity in engaging the hospital reporting contexts due to over-communication. Contrary to the enhancement of participation, too-thick messaging was observed to reduce the perceived importance of individual communication. Based on these findings, the optimal rate of frequency and cognitive absorption is at the optimum cadence at a weekly cycle, an ideal balance between attentiveness and reinforcement.

4.2. Channel Mix

Those facilities utilizing a multi-channel approach, involving the use of digital tools like mobile applications in addition to traditional tools, including posters, notice boards, and face-to-face toolbox talks, registered a significant lowering in incident rates in comparison to single mediums. When the statistical modeling was used, it was found that the number of reportable incidents was 22% less in multi-channel facilities. The findings are consistent with other studies, such as Ebert et al. (2025), that emphasized it is the blended systems that increase accessibility and lessen the weaknesses of having one reporting pathway. The results in commuter safety systems by Uwho and Asianuba (2025) also revealed the same finding in commuter safety systems, as integrated reporting tools increased usability and user confidence.

The advantages accrue to the mining industry, particularly in underground mining, where there are the chances of having the communication barriers that could make the safety activities difficult to accomplish. The use of multi-channel strategies ensured delivery of redundancy in such circumstances, and other channels provided available information, especially in cases where digital signals were not possible. This was justified by compliance data, which indicated that the miners in a multi-channel setting reported incidences of near-misses more frequently, which is in line with the results presented by Tsopa et al. (2025), which indicated that communicating integration could lead to compliance with occupational safety requirements in the coal mines. The indications are that the different and complementary means are not only capable of offering a broad reach but also reduce risks that occur as a consequence of the failure of the systems in the communication. The inclusion of human interest and comfort online may make the facilities potentially more successful at institutionalizing reporting behaviors.

4.3. Readability

Readability analysis indicated that simpler messages, which were organized in a simplified manner, less technical, and easier to follow, were far more effective in raising the participation in reporting. In regard to facilities that were developing safety communications that met the threshold of plain language, a higher engagement rate with near-miss reporting systems was observed, as Osorio et al. (2025) noted the significance of the clear language in patient reports of incidents. Likewise, the study done by Nasution and Ayuningtyas (2024) has seen that the comprehensibility of messages in healthcare facilities was related to the improved adherence in reporting of safety incidents. The miners at the facilities examined made reports 40% more frequently when the bulletins on safety were written in simple and direct, as opposed to technical and long, prose.

In addition to the ease of reading the surface, AI-based natural language processing (NLP) enabled finding out more about the reporting corpus. These reoccurring patterns in large volumes of text-based reports were analyzable in an automatic way thanks to the construction of parsing tools (Antony and Xavier, 2025). The analysis revealed that there were some hidden themes that had recurring issues of the machine, unaddressed issues of the ventilation, and some tacit indication of machine-related fatigue. This realization showing that manual reviewing did not necessarily make self-evident demonstrated the usefulness of Oluwagbade (2025) demonstrating how NLP could be applied in the context of discovering latent risk structures in mining operations. The result then offered by such results facilitates the realization that there is an enhancement in readability, which does not only make it easier for one to participate, but the interpretability of the reports themselves may also be made better after the process. The ability to allow for a greater degree of inclusivity and greater acuity of analytical detail made readability a significant determinant of successful reporting cultures in high-risk industrial settings.

5. Discussion

5.1. Interpretation of Results

The results of this study show that the strategies of communication, like cadence, channel mix, and readability, have quantifiable impacts on the behavior of incident reporting and safety outcomes in mining and processing plants. These findings are in line with the research carried out in the field of the health sector, as the design of communication and its impact on safety culture and reporting rates is critically valuable. As an illustration, Alsobou et al. (2025) also discovered that staff attitudes towards safety culture influenced reporting attitudes, whilst Chaneliere et al. (2024) documented that multifaceted interventions produced a large effect on submissions of incidents in the primary care setting. The similarities identified in them imply that the processes that govern the effectiveness of communication do not depend on sectoral boundaries, and workers in the mining area react in the same way health care professionals would in case they received simple, repeated, and understandable messages.

Inter-industry transferability was also supported by the comparison with construction and care-home safety literature. The near-miss reporting systems provided by Marks et al. (2014) enhanced compliance in construction sites, which is also followed by the mining-focused gains recorded in this study. Similarly, the message design and reporting structures were found to be central in care homes by Scott et al. (2024), which contributes to the idea that the principles of communication behind incident reporting are universal across a wide range of high-risk settings. These results highlight the importance of existing safety-communication approaches in influencing industrial safety outcomes.

5.2. Theoretical Implications

In theory, the study transfers the body of knowledge on the existing safety climatic conditions and reporting models to the industrial mining environment. The study has focused on medical and manufacturing industries, and nothing much has been done on mining, but there are well-documented risks attached to the mining industry. The information represented here shows that the speed and understandability of communication are not peripheral attributes of the safety culture but one of the fundamental determinants. Shaikh et al. (2025) demonstrated that the occupational health and safety management directly caused occupational turnover intentions in the mining segment, whereas Kravchuk et al. (2024) emphasized the direct relationship between safety measures adherence and organizational structures. Integrating these perspectives, the study hypothesizes that modeling of the communication practices should be viewed as a force of compliance in the safety climate.

Moreover, the use of AI-based text analysis may be viewed as a signifier of the use of online tools in the risk management systems. According to Aror and Mupa (2025), artificial intelligence would enhance risk management in the company by identifying patterns that are not represented. Kalu-Mba et al. (2025) placed similar emphasis on policy implications of AI as an organizational innovator. This study can contribute to the existing theoretical argument on how the emerging

technologies can be incorporated into the conventional safety framework in identifying and mitigating industrial risks by using NLP to analyze safety reports.

5.3. Practical Implications

The research is a roadmap from the level managers at the facility to practitioners. The reduction in the number of weekly floors (communication cycles) and the multiplicity and simplification in understanding messages were associated with measurable variations in the incidence reporting and the reduction of incidents. These lessons in real life are helpful to the mining operators who are struggling with the issue of underreporting, which has been a thorny issue in the industry. According to Zeqiri et al. (2022), one of the best predictors of latent risk is near miss data, which is underutilized. Similarly, Tsopa et al. (2025) also found out that one of the keys to the solution of non-compliance in the coal mining business is regular communication. Codification writes the safety communication strategies into the playbook, thus giving managers an opportunity to make the safety communication strategies more than peripheral.

Besides mining, the findings would be applicable in other related fields such as nuclear and uranium processing whereby the risk containment is premised on the reporting system. Meadrado and Gibaut (2024) conceived of a system for categorizing unusual events at uranium facilities that made it important to provide a robust communication structure for high-stakes situations. The existing literature suggests that improvements to readability and cadence may be of equal value in these areas, especially where technical complexity may obscure the definition of safety messages. Therefore, while the former is the main input to mining, the lessons learned serve as good to the overall ecosystem of the risky industrial activities.

5.4. Limitations

The limitations to the study are also notable despite the contributions of the study. First, the reporting biases of using both archival and self-reported data would arise since workers would take an implicit action of underreporting cases either due to an implication of being punished or just due to the perception that they are wasting their time. This has been reflected in the literature in the health care profession, where Nasution and Ayuningtyas (2024) cautioned that archival information might as well be reflective of the organizational policy and not solely individual behaviors. Second, it was limited in terms of geographical location, and it is not clear that the findings could be generalized. As observed by Barozai and Panezai (2024), there is indeed the presence of the regional disparity of the safety practices within the mining sector of Pakistan, but Shaikh et al. (2025) have shown the presence of the socio-cultural disparity as the significant factor contributing to the development of the safety culture in different mining environments. Such contextual factors refer to the idea that despite the fact that the specified communication strategies can be referred to as quite universal, the fact of their performance being influenced by the cultural norms, legislative provisions, and the regional operational obstacles should not be ignored.

6. Conclusion and Recommendations

This paper has demonstrated that effective, reasonable, and well-founded safety communications may be of paramount importance in both reporting incidents and also preventive processes of the mining and processing plants' occupational dangers. The role of dependent and organized communication as the extreme in motivating the farther reporting culture would be fulfilled with the assistance of the analysis based on the message cadence and channel mixture and readability, which the near-miss incidents would rather have happened and could be accompanied by the worst-off incidents. These results give credence to the concept that safety messages cannot be treated by an organizational change but by some essential element of backing up and risk-taking operation.

According to these findings, it is possible to make a number of recommendations to practitioners and policymakers in the mining industry. First, managers need to work on regular, but not excessive, communication schedules, so the messages get repeated often enough to keep the awareness high and the message fatigue low. Second is that the delivery of AI-improved surveillance technologies is tailored to content and delivery of safety messages to be dynamically optimized in terms of readability and frame (Oluwagbade, 2025; Ebert et al., 2025). Third, the facilities are recommended to have integrated systems of communication to leverage both face-to-face briefing and other digital platforms to ensure the high level of access to different groups of workers (Uwho & Asianubu, 2025; Nogueira et al., 2018). These hybrid solutions do not simply mitigate the occurrence of incident rates; they improve adherence to safety standards in areas where it is aloof from risk in industrial functions.

In further studies, it is highly arguable that longitudinal trials using AI can be conducted in order to determine the effectiveness of adaptive messaging systems in the long term and in different geographies (Aror & Mupa, 2025; Kalu-Mba et al., 2025). There should be cross-sector exchangeability of such reflections to incidental examinations delving

further into risky businesses as compared to mining, like chemical, nuclear, and heavy industries. On a broader level, one can gauge the safety communication and the implementation of data chains in a non-data-motivated and yet dynamic fashion; they provide an avenue to refine the cultures of danger in some more significant industries.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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