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**ORIGINAL RESEARCH ARTICLE**

# Catalysts to catapult digitalization in power sector-an outlook

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## ABSTRACT

Workplace digitalization has ample advantages. It helps improve safety, efficiency, productivity, security, transparency, and sustainability to name a few. Further it minimizes human errors, brings a single point of truth out, promotes transparency and collaboration, boosts operational intelligence, and reduces costs. Despite such a plethora of benefits, digitalization could not grow as much as it is expected to be in the power sector due to an umpteen number of challenges. This paper presents a study on such challenges for digitalization in power sector and catalysts to overcome them and a framework achieve the clear-headed digitalization.

***Keywords:*** analytics; digitization; digitalization; digital transformation; real digital twin; drones; APM; EAM; automation; visualization; PADO; AI; IoT; ML; OT; workplace digitalization; SDG7; SDG13

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## 1. Introduction

Workplace digital transformation is the assimilation of digital technology into OT with proper HMI, basically altering how one operates and delivers products or services, adding value benefitting workers and organizations. Despite a plethora of benefits, it has not grown to the extent it is expected[1] in the power sector[2].

The present study limits its boundary to coal fired power plants, in India. They are facing enormous challenges due to load fluctuations on account of the intermittent and uncertain renewable power generation trends[3]. This induces unwanted stress and fatigue in the plant components[3]. Ergo technology adoption to balance between accurate forecast of renewable power generation and a faster/flexible response of coal fired power generation to the renewable power variations is the need of the hour[4].

It furthers safety, reliability, security, stability, and sustainability[5–7] in addition to minimization of human errors, bringing single point of truth, promoting transparency and collaboration, boosting operational intelligence and cost reduction[8]

## 2. Materials and methods

The authors' endeavor was to discover all challenges that are factoring in IT-OT mismarriage[9] in power plants and devise a framework[10] to overcome the same.

An exploratory research nature to explore the reasons for digitalization not spreading vividly in power sector. Abductive reasoning is adopted as the focus is on cause and effect rather than inducing specific rules or deducing truths. A qualitative research design helped the "why" question behind the challenges and casual relationships. Survey, structured interview, and Delphi method[11] were the research strategies that carved the shape of this research journey.

A literature review was carried out on 64 resources like reports published from academia, companies, institutes, press releases, white papers, asset management sites, research papers, etc. At first, relevant articles and papers were searched using key words. Then they were shortlisted using filtering criteria. A deep dive was made into the shortlisted articles. The year of publication wise number of papers/articles reviewed is provided in **Table 1**.

**Table 1.** 64 papers-year of publication wise.

| 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | Other |
|---|---|---|---|---|---|---|
| 5 | 5 | 8 | 13 | 19 | 6 | 8 |

# 3. Results

The results are obtained in three stages. First stage: Through literature review. Collation of challenges. Classifying the 90 challenges in six buckets. Second stage: A google survey was carried out among 110 SMEs, OEMs, end users, and academicians seeking to rank the top three factors in each bucket. Third stage: Focused interviews were conducted to address the 18 salient factors and suggestions were sought through a brainstorming workshop to overcome them; Then the Delphi method[11] was adopted in developing a holistic framework for fostering an effective IT-OT marriage.

## 3.1. First stage-challenges for digitalization

In the first stage a thorough literature review discovered ninety (90) challenges put in six buckets as below (acronym "SORTIE"): Please refer **Tables 2** and **3**.

- **Strategy** (realigning business processes for product/service delivery)[12]
- **Operational excellence** (realigning people, process, and tools)[7]
- **Regulations** (codes, standards, rules, mandates by government, regulators)[7]
- **Technical** (IT-OT-ET convergence)[13,14]
- **Innovations** (that gel well with the needs of the power sector)[15,16]
- **Economic considerations** (investment, short/long term benefits, ROI)[9]

**Table 2.** 64 papers-topic wise.

| S (strategy) | O (operational) | R (regulatory) | T (technical) | I (innovation) | E (economic) |
|---|---|---|---|---|---|
| 16 | 12 | 5 | 17 | 5 | 9 |

**Table 3.** 90 Challenges-topic wise.

| S (strategy) | O (operational) | R (regulatory) | T (technical) | I (innovation) | E (economic) |
|---|---|---|---|---|---|
| 18 | 20 | 13 | 13 | 12 | 14 |

## 3.2. Second stage- top three challenges for digitalization in each bucket

In second stage, a google survey was carried out among 110 SMEs, OEMs, end users, and academicians seeking to rank the top three factors in each bucket. 95 responses received are highlighted in blue.

There were 18 factors in the strategy bucket[17] that hinder an effective IT-OT deployment in power plants[18] and 20 in operational excellence[18] bucket listed in **Table 4**.

**Table 4.** 18-strategy factors and 20-Operational Excellence factors.

| Realigning BP for product/service delivery | Realigning people, process, and tools |
|---|---|
| Context and relevance not clear | Managerial and organizational capabilities |
| Not willing to be the first movers. | Collaboration between departments to seamless implementation |
| Notion that digitation is for services and not for plants. | Lack of Conviction- that digitization supports efficiency and sustainability[20]. |
| Decision maker's dilemma | Effort expectancy |
| Disconnect between management, business processes and user. | Dearth of capabilities and skills in-house |
| Consumer and other stakeholder's interface | Lack of historic data for making the machine learning faster |
| Transformative leadership | Mindset of experience silos, lack of KT |
| Company culture | Perceived complexity of use |
| Work environment | Perceived loss of power/authority |
| Resilience (enterprise risk resilience)[19] | Privacy breach qualms |
| Customer expectations | Siloes and legacy systems. |
| Lack of effective strategy | Standardization issues affecting custom-tailored needs. |
| Absence of strategic alignment | Threat to job security |
| Missing top management engagement | Trust in data by the company |
| Improper knowledge management strategies | Inflated internal capabilities to undertake the digital transformation. |
| Absence of change management culture | Lacking sense of urgency, POC delays |
| Lack of common thread among strategy, vision, leadership, culture, and staff | Skills mismatch |
| Business model alignment | Lack of talent |
| | Dearth of practical problem-solving |
| | Low qualified and elderly employees |

There were 13 factors in the regulatory bucket that hinder an effective IT-OT deployment in power plants:

1) The dearth of regulations;
2) Misaligned financial incentive especially in regulated markets;
3) Absence of policies that encourage;
4) Central (federal) vs. state concurrencies;
5) Infrastructure, eco system from government;
6) Single window approvals;
7) Tax benefits;
8) Deficiency of data governance;
9) Subsidies and incentives for startups;
10) Not addressing the customers' security and privacy concerns;
11) Data ownership and IP rights;
12) Privacy of individuals vs. understanding of an individual;
13) Market rules of competition.

There were 13 factors in the technology[21] buckets that hinder an effective IT-OT deployment[21] in power plants:

1) Adequacy of existing IT infrastructure[22];
2) Compatibility among existing and proposed technologies/devices[23];
3) Cyber security apprehensions;
4) Domain expertise gaps between IT and OT experts[24];
5) Edge vs Fog vs cloud deployment dilemma[25];
6) Technology diffusion tardiness[26];
7) Inadequate digital infrastructure[27];
8) Technology capability and integration[28];
9) Architecture design[29];
10) Lack of situational sensor intelligence[30];
11) Compatibility and co-existence issue the connectivity layer;
12) Security vs. accessibility;

13) Lack of collaboration in IT, ET, and OT.

There were 12 factors in the innovation[31,32] bucket that hinder an effective IT-OT deployment in power plants:

1) ML/AI based use cases to enhance reliability and efficiency[33];
2) Products to support flexibility in operations;
3) Demonstrability of results;
4) Latency in technology adoption;
5) Energy efficient apparatus/ products;
6) Intelligent sensors[34];
7) Waiting for use cases, proofs, and references;
8) Ignoring or not heeding to the superior functionalities of competitors;
9) Work performed by people vs. computing machines;
10) Providing more resources to IT staff vs. more self-service analytics;
11) Technology impact lags;
12) Pace of change and time to market.

There were 14 factors in the economic considerations[35] that hinder an effective IT-OT deployment in power plants:

1) Balance sheet not supporting (financial constraints);
2) Disincentives for investment due to policy paralysis by the governments;
3) Low load factors due to onslaught of renewables resulting low revenues;
4) Huge dues remain to be realized constraining working capital;
5) Tangibility of benefits is difficult to demonstrate;
6) Features with no benefits to customers. Reluctance to pay for that;
7) Aggregate data or personalize (centralization vs. decentralization);
8) Storing all data vs. selecting data to store that serves a specific purpose;
9) Distributed value creation and capture;
10) Investments friendly POCs;
11) Insufficient funds for digitization of the process;
12) Digital technologies enable a circular economy;
13) Priorities (competing and conflicting);
14) Payments from savings-based investments.

### 3.3. Third stage—A framework to catapult workplace digitalization

In the third stage, focused interviews were conducted to address the 18 salient factors and suggestions were sought through a brainstorming workshop[36] to overcome them. Then the Delphi method was adopted in developing a holistic framework for fostering an effective IT-OT marriage. It encompasses identifying workplace digitalization projects, securing internal buy-in, implementation, enabling and tracking performance, monitoring, and reporting progress[37–39] as in **Figure 1**.

A cross functional team (POG) is to be formed which does the techno economic review (TER) of proposed IT-OT projects considering the existing overview and a feasibility check. They collect the prerequisites, features, and sought after benefits for solutioning and KPI based use case development.

Then the SORTIE challenges (both internal and external) are resolved with the concerned process owners converging on alternatives. A cost benefit analysis (CBA) is carried out on the selected alternatives to compare. An informed and consensus decision is then taken to choose the IT-OT project for implementation. Budgets are allocated.

Project management office (PMO) is assigned end to end (E2E) responsibility from concept to commissioning, design[40], monitoring, and controlling budget, quality, and schedule.

This framework is deployed, and several digitization projects were rolled out cost effectively with agility.

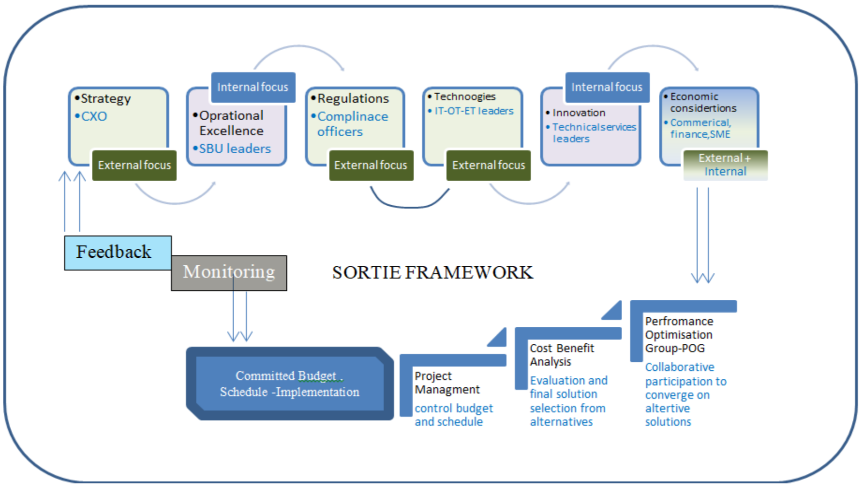


**Figure 1.** Framework.

# 4. Catalysts for digitalization

Present day employees expect to work in an environment that supports their creativity and personal growth. The workplace digitalization is hailed by the employees as it enhanced their productivity[41], wellbeing and resulted in better stake holder management contrary to initial apprehensions of threat to their jobs. Further the changing and aging workforce, need for easy access to data, mistakes reduction goals, accountability, transparency, safety compliance goals act as drivers. It balances authority and workflow breaking siloes.

## 4.1. Use cases

Use cases[42,43] of workplace digitalization have three elements user, purpose, system[44].

Several companies offer their workforce smartphones, tablets, gadgets, PDA enhancing their workplace mobility providing flexibility and autonomy in terms of time, space, and content of work. Core business applications (ERP, CRM), collaboration applications (video/phone/IP based conferencing, interactive meeting room technology) and administrative applications (access control, attendance) with proper connectivity facilitate effective IT-OT integration. **Figure 2** depicts remote monitoring and diagnostics center where virtual controls and operational Optimisation can be attained[30].

**Figure 2.** Communication and collaboration tools.

Ensures the flow of tasks, documents and information is performed independently per business rules. For example, automated emails, alerts, escalations, approval hierarchy through BPM or RPA. **Figure 3** illustrates the workflow automation through BPM and RPA.

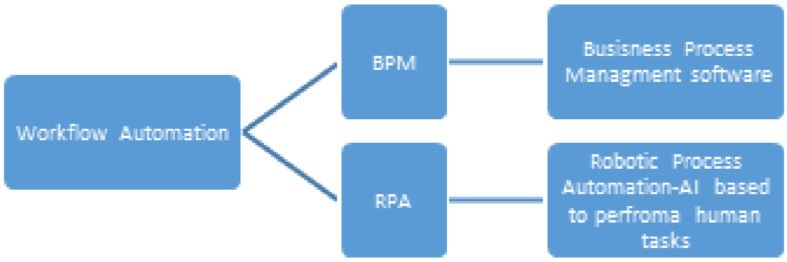


**Figure 3.** Workflow automation.

**Figure 4** below shows the IMS and KMS continuum.

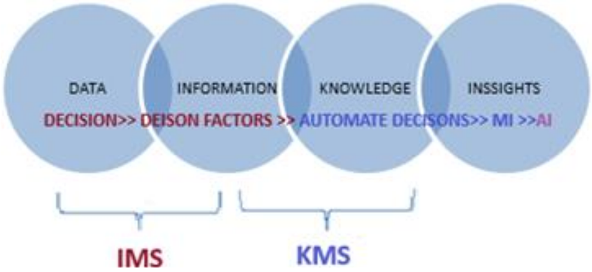


**Figure 4.** Information and knowledge management systems.

**Employee onboarding and training:** VR creates a 3D virtual environment in which the user is completely immersed and can be used in field staff training and virtual site visits. AR is a technology that uses technological equipment (for example a camera lens) to augment the real world around us and could be used for training of workforce and employees.

**Reduced operational costs:** Automated tasks, reduced errors optimize workflows resulting in improved productivity, and reduced costs.

**Asset performance tracking and analytics:** Asset Performance Management utilizes advanced analytics to assist in adopting and practicing better predictive and prescriptive maintenance procedures[45]

**HR and employee management:** Using SMAC technologies HR can leverage digitalization to be more effective and connected. Future-proof recruitment (a data-driven preselection process and a personalized, AI-based onboarding program) is a nice example.

**IT service management:** ITSM facilitates the end-to-end (E2E) delivery of IT services viz., concept to commissioning and beyond.

**AI based interactive toolbox talks:** Providing a 360 degrees perspective of the hazard in a job, job safety analysis, point of work risk assessment, last minute risk assessment[46].

**I-care, I-auditor applications:** They are very useful in carrying out our local walk-down checks, Gemba walks, safety walks, executive walks, executive observations, etc.

**Lifesaving apparatus monitoring:** Usage training like automated external defibrillators (AEDs), self-contained breathing apparatus (SCBA), etc.

**SOS wristwatch:** Provides a beep sound or alerts through vibrations when a person unintentionally enters a prohibited area.

**Advanced analytics (Figure 5):** Advanced analytics aid in near accurate forecasting of demand and supply corelating with historical data, facilitate seamless integration from field to board room goals realization[47,48].

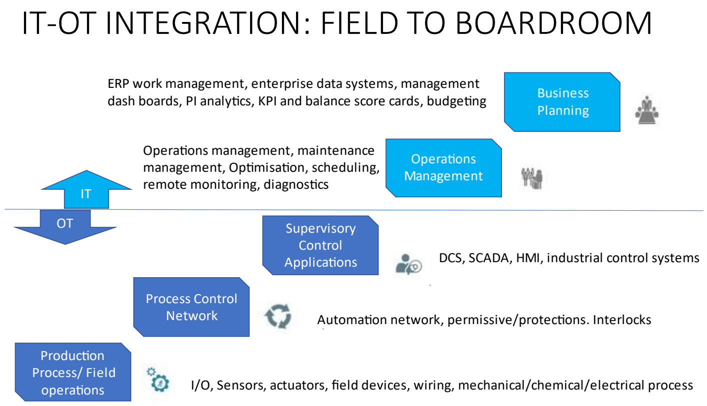


**Figure 5.** Advanced analytics.

**IOT penetration (Figure 6):** With the decreasing cost of sensors more connected devices are being deployed IoT to enhance reliability[49–56].

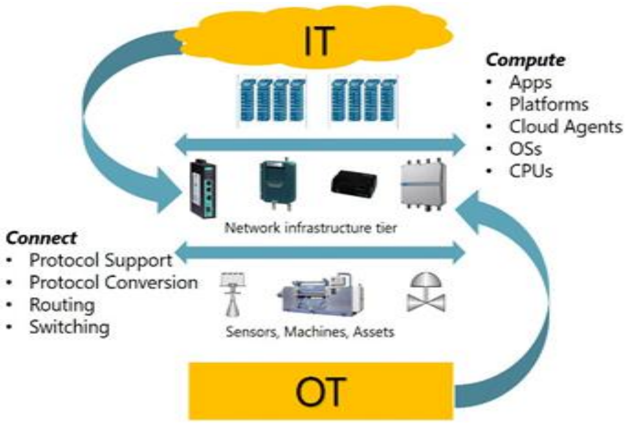


**Figure 6.** IOT penetration.

**Asset value optimization (Figure 7):** ISO 55,000 defines asset as a “thing, item or entity that has actual or potential value”. Asset-intensive electric utilities strive to realize the true potential of their assets through Asset Performance Management[57] APM encompasses planning and scheduling, work order and permit to work management, sourcing, and procurement management[58], EHS management coupled with SCADA, DAS, DCS integrated through IIoT.

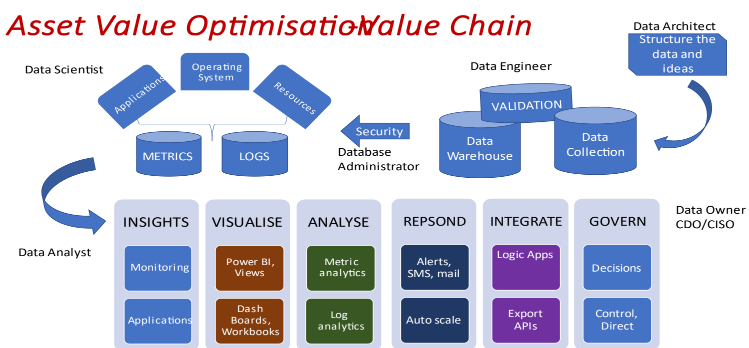


**Figure 7.** Asset value optimization.

**Transmission and Distribution strengthening:** From steady state SCADA EMS systems there is a move towards dynamic monitoring of grid using phasor management unit (PMU) and wide area measurement (WAM) which brings in features like remedial action services (RAS), system integrated protection scheme (SIPS), adaptive islanding, self-healing grid, etc. in transmission and distribution (T&D) systems, etc. Advanced distribution management system (ADMS) shown in **Figure 8**, is unification of SCADA, DMS and OMS facilitates greater automated control for more efficient distribution.

**Figure 8.** ADMS Display unit.

**Vibration monitoring and analysis system-VMAS (Figure 9):** All critical rotating equipment is monitored and controlled for reliability and adaptive planning. This is one of the best condition monitoring applications.

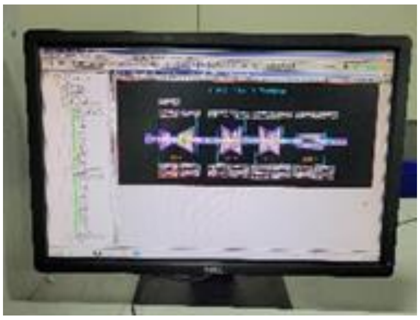

**Figure 9.** VMAS display.

**Deployment of drones (Figure 10):** Application of drones or UAV support real time monitoring and in establishing "Golden records" helping manage the geographic spread of power assets. Drones AI combo find use in boiler inspection, vegetation monitoring, cross country transmission line, pipelines inspections, tall towers like chimney, NDCT inspections, solar and wind assets inspections, warehouse management, coal physical stock verification etc.

**Figure 10.** Deployment of drones.

**AMI (Figure 11):** Advanced metering infrastructure (AMI) consisting of smart meters[59], associated communication devices and software systems lay the foundation for smart grid.

**Figure 11.** AMI.

**CCTV analytics (Figure 12):** Regular CCTV cameras can be turned into an AI Smart[60] camera to ensure safety adherence with automated real-time detection and response system.

**Figure 12.** CCTV analytics.

**Revenue management system—Power distribution (Figure 13):** A unified RMS for both rural and urban customers getting seamless integration with digital payment avenues, easier accounts consolidation/ reconciliation, and greater insights into electricity consumption of consumers.

**Figure 13.** Revenue management system—Power distribution.

**EHSS management:** Continuous emission monitoring system (CEMS), environment, health, and safety (EHS), risk assessment and priority planning (RAPP), ambient air quality monitoring (AAQMs)

**Blockchain innovation:** Adoption of blockchain[61] based solutions improve service-delivery leveraging cost reduction and effective contract management through creation of a single, consolidated, and immutable record of transactions.

**Enhanced productivity with minimum downtime:** Digitalization facilitates effective Root cause analysis (RCA), failure modes and effects analysis (FMEA), robotic process automation (RPA), management of change (MOC).

**Operations management:** Other asset motoring and optimization use cases include performance analysis and diagnostic optimization (PADO), condenser health monitoring[38], generator health monitoring (GHM), energy management system (EMS), online dissolved gas analysis (DGA) for transformers, intelligent soot blowers, digital worker (log), turbo supervisory instrumentation (TSI), turbine stress evaluator (TSE), availability-based tariff (ABT), Boiler tube leakage detection system (BTLDs). BTLDS unit is shown in **Figure 14**.


**Figure 14.** BTLDS.

**NFC based equipment local visits/inspections (Figure 15):** Using this feature, the operator must go near the equipment and scan the "near frequency code" (NFC) to enable the relevant form pertaining to that equipment open, before logging in parameters ensuring local visits must.

**Figure 15.** NFC based equipment local visits/inspections.

**Industry 4.0** (**Figure 16**)**:** Industry 4.0[62] (plant components and machines can think and communicate with each other using AI and ML, AI powered heat balance diagrams with simulation capabilities, data driven cloud-enabled enterprise, AI ML for descriptive/ diagnostic/ predictive/ prescriptive analytics[63], communications, protections and interlocks, unit start up curves. HMI interface for diagnostics[64].

**Figure 16.** Industry 4.0 Application.

**Cyber security (Figure 17):** The central energy regulatory commission emphasizes the significance of cyber security. CISO-chief information security officer is responsible ensuring cyber security using mitigation mechanisms.

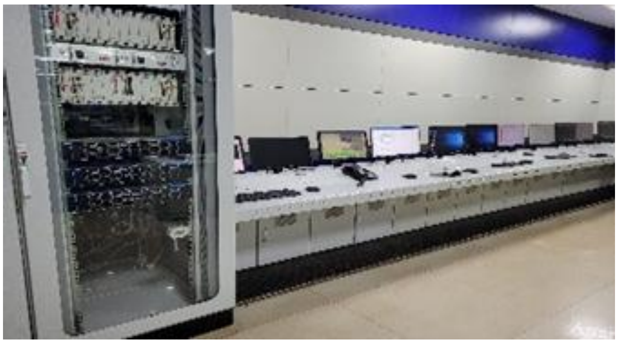

**Figure 17.** Cyber security through de military zone and fire walls.

## 5. Conclusion

Both industry and academia are struggling to pave a clear path to enable seamless integration of IT-OT. The research work and framework would help strengthen the novel business models[64] overcoming current challenges in marrying IT-OT effectively.

The discussed catalysts and use cases can catapult workplace digitalization by deploying SORTIE framework. This framework has helped in agile deployment of digital initiatives in our power plant. As a way forward totally outsourced model or public private partnership (PPP) model can be studied with respect to funding and returns management from digital projects.

Power plants can think big but must start small, do POC, roll out, implement, experience, and scale up. They can begin with asset visibility in the field level, and gradually expand to operational confidence in the control room level, performance orchestration at the plant level, and business agility at the boardroom level.

## Author contributions

Conceptualization, KRP and VV; methodology, KRP; software, KRP; validation, VV, KRP and SME; formal analysis, KRP; investigation, KRP; resources, VV; data curation, KRP; writing—original draft preparation, KRP; writing—review and editing, VV; visualization, KRP; supervision, VV; project administration, VV; funding acquisition, NA. All authors have read and agreed to the published version of the manuscript.

## Conflict of interest

The authors declare no conflict of interest.

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