Technology-Enabled Assessments Support Remote Care of Oncology Patients and Improve the Care Team Experience

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Oncology researchers have significant evidence documenting the consequences of febrile neutropenia; these and other fever experiences can lead to significant morbidity and mortality. Acute care costs from malignant crises and sepsis events can be significant and burdensome.[1] Approximately 50% of patients with febrile neutropenia will develop an infection, of which 20% with profound neutropenia will develop bacteremia.[2] In a study presented at a National Comprehensive Cancer Network Annual Conference, Wang stated, "Patients treated with intermediate-risk regimens had a higher likelihood of febrile neutropenia than those given high-risk regimens."[3] This study reported odds ratios of 1.6, 1.7, and 1.8 for main, sensitive, and specific definitions, respectively; all $P < .05$.[3]

Efforts to reduce the impact of febrile neutropenia began by developing guidelines, which recommended that patients with cancer receive antibiotics within 1 hour of fever onset. Later studies focused on the cost of care and improving quality of life for those with febrile neutropenia. These studies demonstrated that ambulatory treatment is a safe and feasible option for patients with low-risk febrile neutropenia, and that treatment in this setting is associated with savings in resources, reduced risk of nosocomial infections, and improved quality of life.[4]

The Multinational Association of Supportive Care in Cancer (MASCC) and the Clinical Index of Stable Febrile Neutropenia (CISNE) scores are models developed to determine risk(s) associated with febrile neutropenia. While the CISNE is validated to predict significant complications in patients with a score of ≥ 3, there are limitations to its use in broad patient populations. The MASCC score has produced variable results.[4] One of the drawbacks of these models was a need for inclusion related to factors influenced by the patient, treatment, and the sheer coordination required to manage a patient in the outpatient versus inpatient setting. These prevent health data scientists from reaching population-level conclusions that include essential community members.[5]

In addition to prediction models, data have shown that it is possible to de-escalate or discontinue antibiotic therapy regardless of the absolute neutrophil count without impacting clinical outcomes.[6] These efforts to reduce the impact of febrile neutropenia have taken a limited view of other symptoms that may occur or how symptom context might guide clinical care. Electronic patient reported outcomes (ePROs), and wearable health technologies allow for a better understanding of a patient's experience. These tools may provide greater insight into reducing the impact of febrile neutropenia, including data-driven, timely febrile event identification and intervention.[7]

> Technology is the catalyst for the successful adoption and implementation of ePROs because of its ability to display nuanced experience details in simple and interactive graphs.

Improving the Patient Experience and Health Equity

In the United States, health care equity and access remain critical issues, with disparities disproportionately affecting marginalized communities. Achieving equitable health care requires addressing socioeconomic factors and systemic barriers and ensuring access to quality care for all individuals, regardless of their background. Frontline health care professionals are pivotal in bridging these gaps, advocating for patients, and delivering culturally competent care. Additionally, advancements in health technologies offer promising solutions to improve access, increase efficiency, and tailor health care delivery to diverse populations.[8] According to a report from the National Academies Future of Nursing, nurses are critical to achieving health equity.[9] To improve clinical outcomes, this consensus report suggests that health care organizations:[9]

- Have a diverse, large, integrated workforce
- Focus on preventive person-centered care
- Have an orientation toward innovation
- Work in new settings in new ways
- Engage in complex work to improve well-being at individual, family, and community levels
- Help to ensure that individuals receive equitable health care services.

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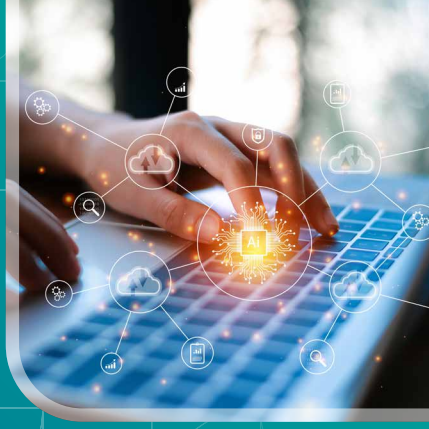

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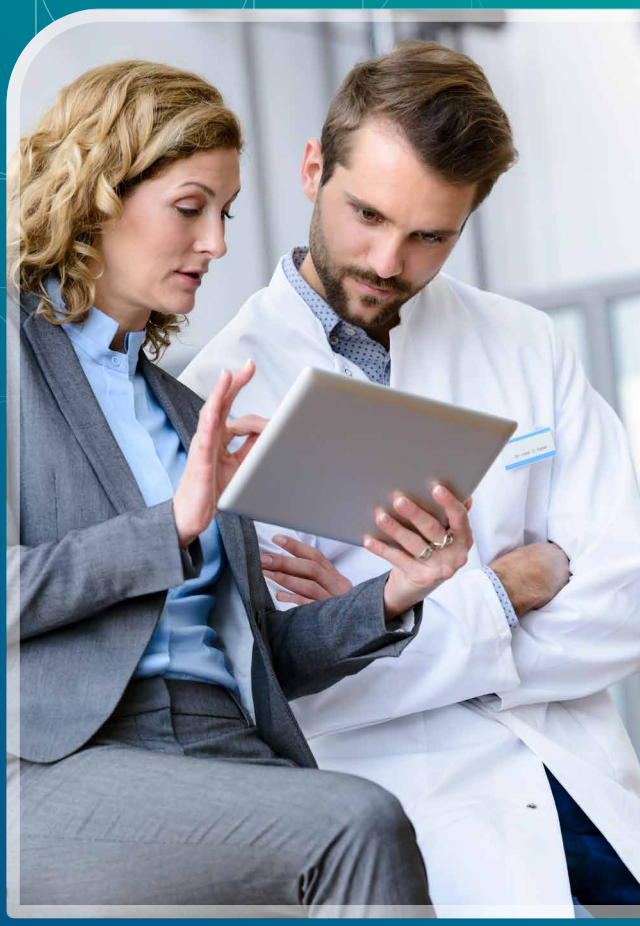

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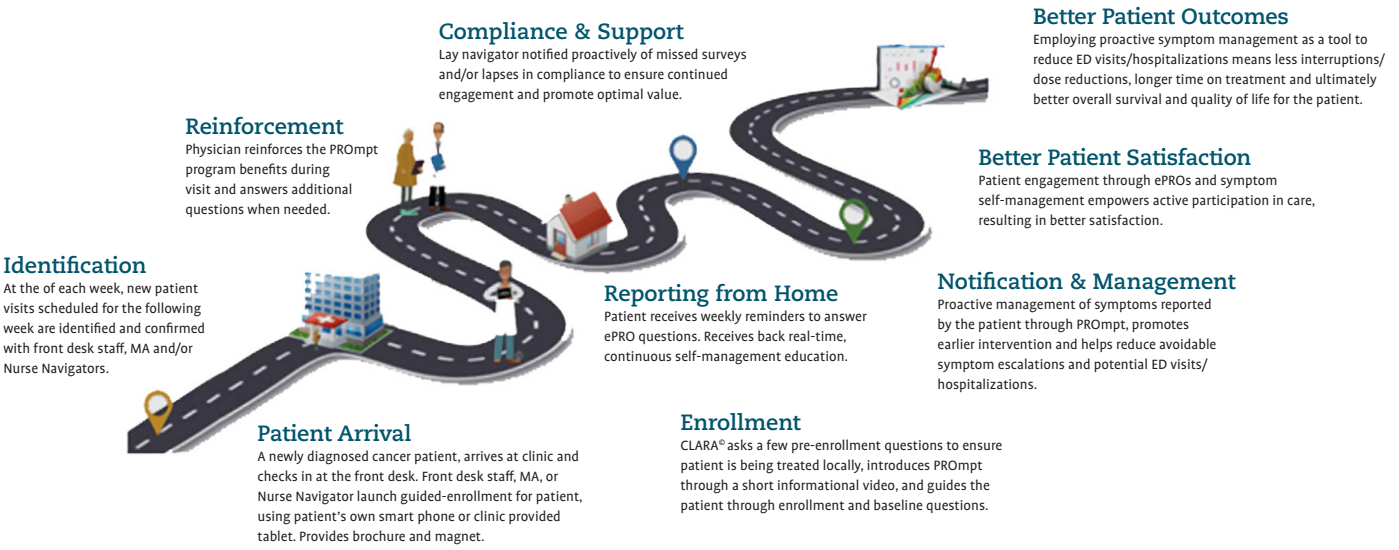
Figure 1. Illustration of the Patient Journey



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The Role of Technology

Patient-facing health tools that leverage the same data that providers use but present data to patients and caregivers using personalized and lay-appropriate displays offer more persons of every attribute the opportunity to achieve a level of data contribution transparency that meets their information security needs on a personal level. Patient-reported outcome (PRO) measures like PRO-CTCAE and PROMIS empower patients to rate their symptom toxicity, adverse effects, and other care concerns. While PRO science has evolved more slowly than desired in the United States compared with other nations,[10] potential health improvements related to ePRO use include quality of life enhancement, reduced acute care visits, and extended overall survival.

Technology is the catalyst for the successful adoption and implementation of ePROs because of its ability to display nuanced experience details in simple and interactive graphs. ePRO reports can potentially decrease health system bottlenecks and personal and/or cultural bias by increasing efficiency and removing provider interpretation of symptoms. **Figure 1** illustrates how ePROs can help support and improve patients with cancer as they navigate through the health care system.

Effective use of these technologies allow health care providers to better understand patient populations and focus their attention on providing equitable care. Cancer care teams need all the support they can get to collect and respond to their patients' symptoms and experiences. New staff need innovative resources and dependable algorithms. Experienced staff need relief from the stress of maintaining internal knowledge systems; rather, experienced staff should be relied upon and honored for their contributions to dependable clinical assessment and response resources.

In 2019, the World Health Organization stated that "digital transformation of health care can be disruptive" and identified the technologies and their potential impact on health care (**Table 1**).[11] Technological improvements now allow for more efficient and

Table 1. Disruptive Digital Technologies

Technology	Potential Impact on Health Care
Internet of Things (IoT)	Enables remote monitoring and data exchange for improved health care
Virtual care	Facilitates remote health care services, enhancing accessibility
Artificial Intelligence	Improves medical diagnosis, treatment decisions, and digital therapeutics
Big data analytics	Enhances data-based treatment decisions and supports clinical trials
Blockchain	Enables secure and transparent data exchange across the health ecosystem
Smart wearables	Aid in remote data capture and monitoring for personalized care
Platforms	Facilitate data exchange, storage, and sharing across the health ecosystem
Tools for remote data capture	Support remote monitoring and enhance data collection for health care
Continuum of care	Fosters a seamless and integrated approach to health care delivery
Person-centered care	Emphasizes individualized and patient-focused health care
Evidence-based knowledge	Contributes to the development of evidence-based health care practices
Skills and competence	Support the continuous development of health care professionals

practical remote patient monitoring. Wearable device utilization in oncology has been focused more on consumer-driven devices, with few devices having received Food and Drug Administration (FDA) clearance.

Wearable and mobile technology provides a cost-effective and scalable means for oncology programs to implement remote and real-time patient monitoring. "By leveraging this technology, health care providers have access to both objective and patient-reported health data to facilitate clinical decisions that may result in better adherence, quality of life, and treatment outcomes."[12] There may also be a benefit from the adoption of mobile and wearable devices in clinical trials, which may "standardize data collection and capture more precise and frequent data to better inform study designs and to improve understanding of the clinical benefits of therapies,"[13] without the heavy overhead and labor-intensive (person-resource) costs associated with more traditional data collection efforts.

In 2023, the Digital Medicine Society and Moffitt Cancer Center held a roundtable discussion on using innovation in oncology.[14] These organizations identified challenges in adopting and implementing digital technologies, such as a poor understanding of which challenges in cancer care could benefit from digital technologies, which research areas are most suitable to utilize digital technologies, and a lack of incentive and support to carry out those implementations.[14] Fortunately, health care providers and government agencies are addressing some of these challenges by developing remote patient monitoring and nurse navigation codes, which enable reimbursement for educating and monitoring patients remotely.[15]

As health care organizations continue to harness the power of technology to improve cancer care delivery, exploratory feasibility projects have become essential testing grounds. With these projects, health care technology groups can proactively obtain a large number of measurements from patient and care team experience in a relatively short time, allowing for observation, adjustment, planning, and contextualization of information and insights to inform large-scale studies, projects, and rollouts.

A Feasibility Study

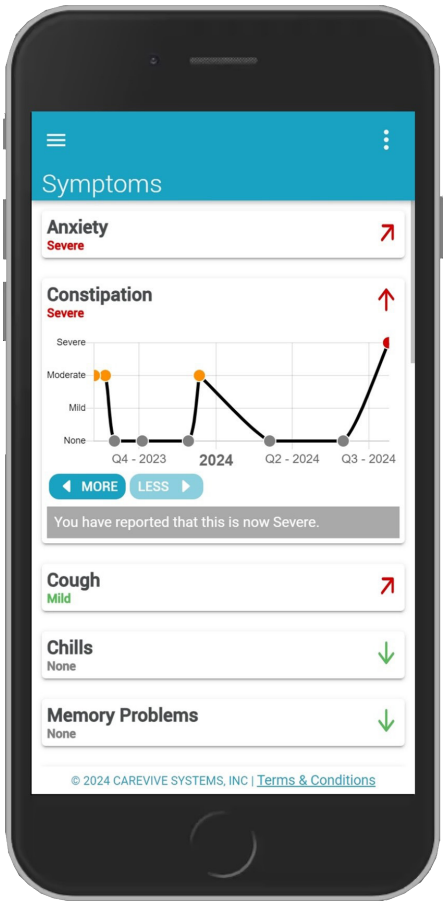
Carevive and Blue Spark Technologies collaborated to explore the value and efficiencies of a detailed temperature and symptoms dataset for at-risk patients with the long-term vision of supporting clinicians in assessing and prioritizing patient reporting of fever during an anticipated nadir. Researchers hypothesized that use of ePROs and complementary remote monitoring services for continuous temperature monitoring could guide improved clinical decision-making for adult oncology patients experiencing fever. Researchers also conjectured that additional information gathered by ePROs and continuous temperature monitoring could improve the evaluation of patients with febrile neutropenia to assist with early intervention and antimicrobial stewardship.[16]

Carevive and Blue Spark Technologies sought to gain clinician and patient feedback across multiple sites to support project expansion and workflow enhancements. To do so, researchers reached out to current customers and initiated cold-call conversations to assess interest in project participation. While most health organizations were enthusiastic about the tools and the potential value to patients and care teams, they faced barriers to participation, including a need for funding and competing priorities; some organizations requested consideration for future projects.

For this study, 2 cancer centers enrolled 11 patients undergoing treatment for hematologic malignancies. One site approached the project through an Institutional Review Board addendum to a related study, and the other site used the project as a quality improvement initiative. Both participating sites had a prior working relationship with 1 of the technology platforms. Both sites were forward-thinking academic oncology programs interested in supporting their patient care capabilities with innovative technologies informed by experience. Patients participated in the project with the support of a provider champion who was interested in the study and was able to speak with patients about the potential value of the project's tools and goals.

Carevive PROmpt® is a remote symptom monitoring and ePRO assessment tool that brings questions to patients via their mobile device or computer and then records responses into electronic health record (EHR)-integrated dashboard displays for personalized clinical care. The ePRO platform was used to send weekly health and symp-

Figure 2. ePRO View on Smart Phone



tom questionnaires via text or email, which were then completed on patient smart devices or web browsers (**Figure 2**). Patients entered ePRO symptom data for their health care teams to view on the platform at baseline, daily during their nadir, and weekly for a period appropriate to their treatment experience (**Figure 3**).

TempTraq® is an FDA 510-k cleared, Class II medical device that gives health care providers a wireless continuous temperature monitor in the form of a soft, comfortable, disposable patch (**Figure 4**). Evidence generated using TempTraq includes a Cleveland Clinic study showing that in adult intensive care unit patients, TempTraq was in agreement with pulmonary artery catheter readings.[17] A University of Michigan bone marrow transplant and CAR T-cell study showed that fevers caused by infections were detected significantly earlier (median =18.5 hours) using continuous temperature monitoring and that this type of monitoring provides considerable lead time (median 4.9 hours earlier) than the standard of care for early detection of febrile adverse events.[7] Eulji University found that TempTraq had a specificity of 0.86 and sensitivity of 0.85 in pediatric patients compared to tympanic thermometers and that overall patient and parent satisfaction with use was high.[18]

The technology platforms provided cancer care team members with patient data displays to support clinical decision-making. Displays were available on demand and were responsive to patient input in real time. Researchers assessed patients for episodes of febrile neutropenia and tracked overall continuous temperature monitoring and ePRO utilization. Researchers conducted post-experience interviews to gather feedback on the feasibility and value of ePRO and continuous temperature monitoring from clinician and patient perspectives. Data were analyzed using standard qualitative research methodologies (**Figure 5**).

Results

Two hundred twenty-six days of continuous temperature monitoring data and 138 ePRO questionnaires were available for study consideration. Overall, continuous temperature monitoring and ePRO captured 71 reports (days) of fever. Median continuous temperature monitoring use and ePRO follow-up were 17 days and 16 surveys, respectively. Participants took a total of 148 surveys from August 16, 2022, to June 7, 2023. Patients took 94% of surveys, with 5% taken by the spouse, family member, or partner. Additionally, 80% of the surveys were taken at home, 10% while hospitalized, 8% other, and 2% at the doctor's office. Patient and physician feedback was positive, indicating limited impact on daily activities and workflows.

Researchers conducted patient and site interviews to understand their experiences and to help develop justifications for future collaboration. One patient reported temperature based on how he felt instead of the actual temperature; however, he felt the continuous temperature monitoring patch and ePRO reporting were a "light burden." The 2 participating sites provided feedback, including information about 1 patient's struggle with data connectivity issues related to their limited mobile service plan, which resulted in using only 1 continuous temperature monitoring patch. Another patient used the tools prior to treatment. Site challenges included frequent staff turnover that required retraining at multiple time points.

Figure 3. PROmPt App on Smart Phone

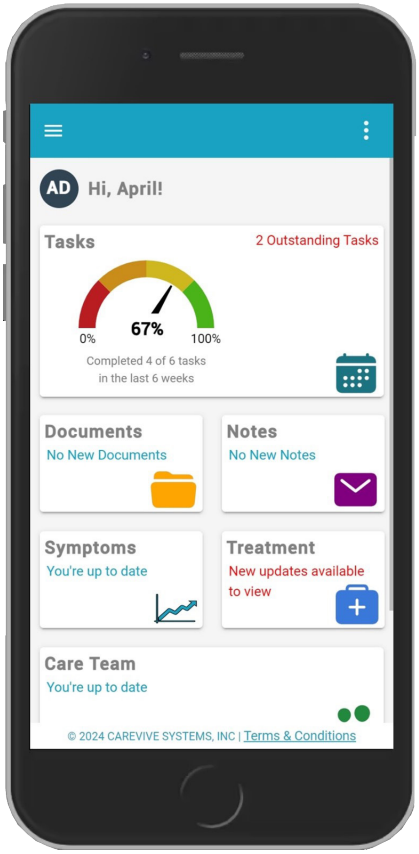


Figure 4. Patient Using Continuous Temperature Monitoring

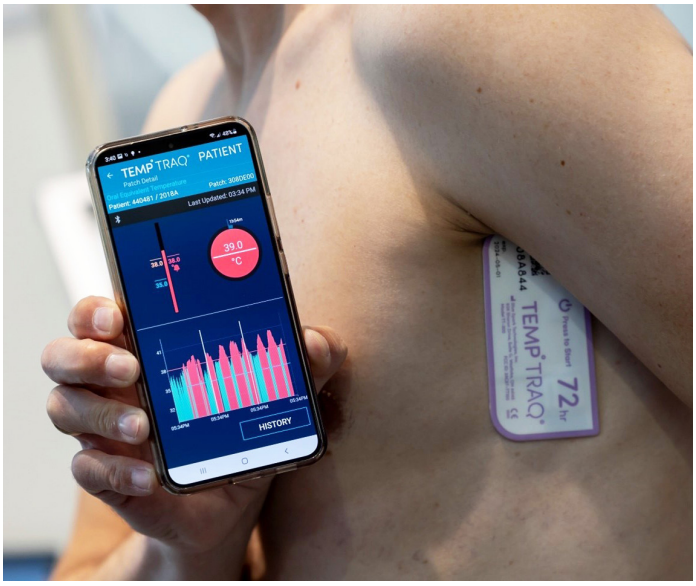


Figure 5. TempTraq Architecture

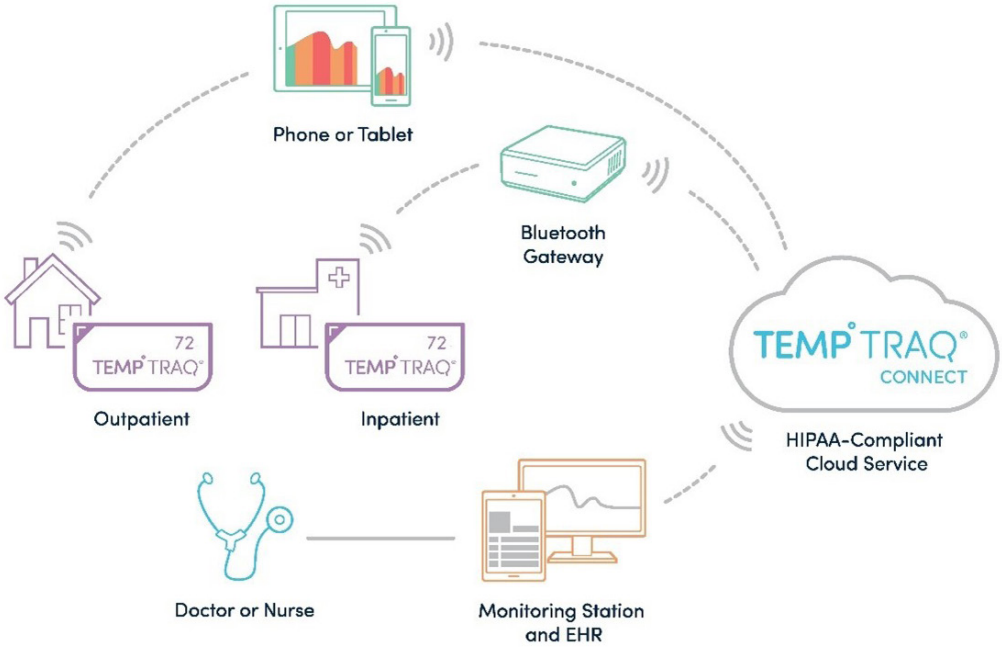


Figure 6. Select Results from Patient Survey

Question	# Responses	Mean	Median	Mode	Standard deviation
Overall, I am satisfied with how easy it is to use TempTraq system.	3	3.67	4.00	4.00	1.25
Question	**# Responses**	**Mean**	**Median**	**Mode**	**Standard deviation**
I believe I can monitor my temperature better using the TempTraq system.	3	3.00	3.00	5.00	1.63
Question	**# Responses**	**Mean**	**Median**	**Mode**	**Standard deviation**
Overall, I am satisfied with how easy it is to use PROmpt to answer questions regarding my health and symptoms.	3	2.67	3.00	3.00	1.25
Question	**# Responses**	**Mean**	**Median**	**Mode**	**Standard deviation**
Overall I feel the use of TempTraq and PROmpt would be good for other patients.	3	4.00	4.00	4.00	0.82

Providers had mixed engagement; although interested in supporting the study, 1 site was reluctant to engage staff to support the education and monitoring of patients.

While the size of the study and the nature of the feasibility project prevents drawing conclusions from the available data, some observations can be shared. Researchers assessed health and overall quality of life using a 5-point Likert scale, with participants reporting an average overall health of 4.7 and an average overall quality of life of 5.0. Patient and physician feedback were positive, indicating limited impact on daily activities and workflow (**Figure 6**). Interestingly, patients did not always report fever even though it may have been identified on continuous temperature monitoring if that fever was not confirmed using another thermometer (ie, oral). Overall, patients found both tools easy to use and valuable.

Discussion

Pilot participation demonstrates patients' and providers' willingness to engage with innovative technologies and provide feedback. The feasibility study also revealed new opportunities to understand technology implementation and use of technology to measure well-being factors (**Figure 7**). For example, 1 of the study patients was a 52-year-old

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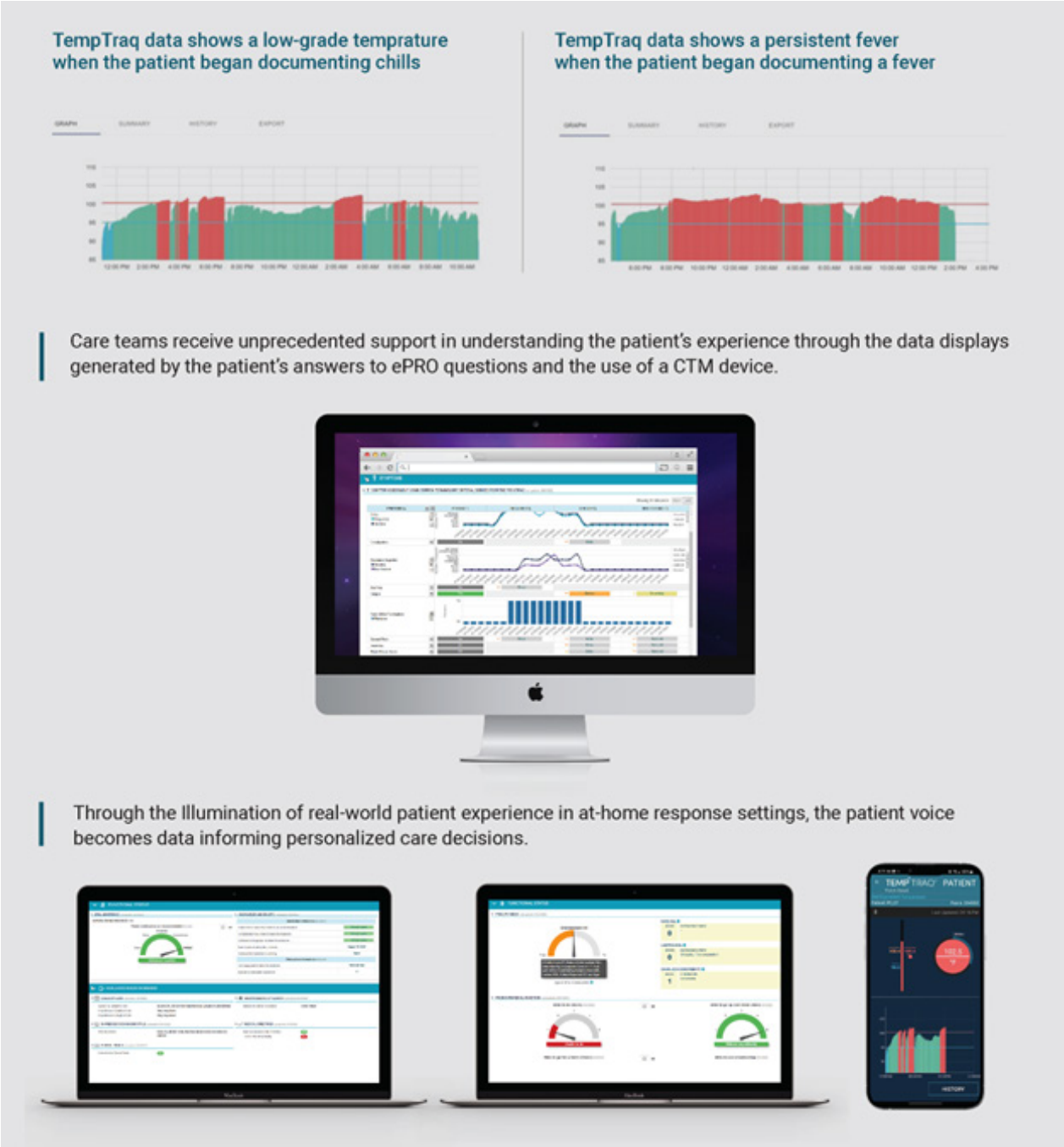
Figure 7. Data Visualization of Pilot Project



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male patient with diffuse large B-cell lymphoma who was at risk for febrile neutropenia related to a standard of care treatment pathway. This patient wore the TempTraq patches and completed daily ePRO assessments during the at-risk period. ePRO assessments were completed for 8 weeks, allowing trending views of at-home self-reported symptoms. Researchers observed that symptoms reported matched literature discussions of fever symptom clusters, such as chills and increased fatigue and pain.

Conclusion

This was a small feasibility project and additional research on the intersection of wearable medical devices (passive ePRO collection) in conjunction with active ePRO collection is needed.

Innovations in technology and the synthesis of these data provide new insights into managing oncology patients who are at risk for experiencing febrile neutropenia and other fever events. Health care providers can use these insights to improve their care quality. Researchers identified value in study planning and design insights. These data provide a patient-centric understanding of the experience of oncologic illnesses within and throughout diagnosis while highlighting potential areas for patient education and early intervention. Pilots, as well as larger studies, are essential for health care teams and organizations to understand how new technologies can support workflows, intervention protocols, and patient education. Projects like this feasibility study also help us better understand patient and care provider experiences with technologies. OI

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