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# IoT Based Smart IV Monitoring and Safety System: A Survey

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***Abstract* - Delivering fluids and drugs through a vein is among the most routine treatments in any hospital. Nurses generally check the bottle with their own eyes and replace it as it nears the end. In a crowded ward, a bottle can run dry with nobody noticing, and that may allow blood to travel back up the tube or air to reach the vein. Numerous researchers have addressed this risk with sensors and wireless alerts. This survey offers a plain overview of the existing ways to weigh the bottle, detect blood in the tube, find air bubbles and halt the flow. The means of passing alerts to the nurse are covered as well. The strong and weak points of every method are compared. The survey also brings out the present challenges and the gaps that are still open, so that safer infusion monitoring can be developed in the future.**

***Keywords - Smart IV Monitoring; Patient Safety; Blood Backflow; Air Bubble Detection; Wireless Alerts; Fluid Level Measurement; Healthcare Automation***

## I. INTRODUCTION

Decades ago, intravenous (IV) therapy was managed by a nurse or doctor who found the drip chamber, counted the falling drops against a wristwatch for one minute and then set a plastic roller clamp by hand. Electronic infusion pumps arrived later and were used for critical patients to deliver medicine at a set rate. Neither of these early options was without a problem. In general wards the fluid was still checked manually, and commercial pumps were too expensive to place beside every hospital bed.

During a hospital stay, most patients receive fluids or drugs through a vein at one point or another. Once a bottle runs empty, the pressure inside the tube drops and the patient's blood can rise up into it. This can clog the needle or form a clot. Air may also get into the tube and pass into the vein, which can be extremely dangerous. In busy wards a single nurse is responsible for many beds, so a bottle may finish before anyone gets to the bedside. For this reason, researchers have tried to design small electronic units that keep watch over the bottle and the tube throughout the day and tell the staff when action is needed.

The smart IV monitoring problem splits into two main stages: fluid level detection (or tracking) and safety control (or protection). Detection is the first stage. It covers working out how much liquid remains in the bottle and spotting air bubbles or blood in the drip tube. Safety control is the second stage. It covers the wireless alerts that reach the nursing station and the automatic clamping of the tube, which stops the flow before the patient is harmed.

Nurses are well aware of what can go wrong when an infusion is left unwatched. If the fluid stops without warning, the treatment is interrupted and the patient may miss an important dose of medicine or fluid. If blood enters the tube, the needle may get blocked and the vein may have to be punctured again. If air gets into the line, it can move along with the blood and do serious damage. Such events are uncommon but severe, and they can be easily avoided if the bottle is checked at the right moment.

Many countries have too few nurses and a rising number of patients. A nurse with many beds to cover cannot remain close to every bottle. This is the chief reason that researchers in electronics and computer science have taken a strong interest in smart IV monitoring over the past few years. Low-cost sensors, small controllers and ordinary wireless links now make it possible to build useful devices on modest budgets. The work that followed drew on many different ideas, and the field has therefore grown fast.

This survey gathers the existing approaches in a clear sequence and explains where each performs well and where it is lacking. Studies from 2020 to 2026 are included, so that the current direction of the field is visible. Only the published work of other researchers is discussed in this paper.

## II. METHODS

Infusion monitoring usually starts from two things: the bottle hanging on the stand and the tube that takes the fluid to the patient. A problem can show up at any point along this path. The bottle may empty. The tube may fill with blood that has moved back from the vein. Tiny air bubbles may travel through the tube. The drip may also run too quickly or too slowly. The place where the device is used matters too. A ward with many beds needs a system cheap enough to install at every bed, whereas a home care setting needs a compact device that can be used without special training. Since these needs differ, researchers have combined sensors and alert methods in different ways. The sections below describe the



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main groups of methods.

### A. Drip Counting Based Methods

Drip counting is one of the first automated ways to monitor IV fluid [10]. In such a system a light source sits on one side of the transparent drip chamber and a receiver on the opposite side. Each falling drop interrupts the light for an instant, and the controller records it as a single drop. This gives the rate of flow. To estimate what remains in the bottle, the number of drops that have fallen is multiplied by an average drop volume. The volume used so far is then taken away from the initial volume of the bottle.

Arfan et al. built a portable device that follows the drip rate and also helps regulate it for precision care [10]. Wang et al. examined a very small sound-wave-based sensor that can likewise observe the drips [13]. Drip counting methods are inexpensive and easy to build. They do, however, rely on the sensor being placed exactly right. A tilted stand, or small droplets of fluid clinging to the chamber wall, can throw the count off. Light in the room can also interfere with light-based counters. Because of these drawbacks, many later studies shifted to weight-based methods.

In practice, drip counting is best regarded as a low-cost starting point. It fits situations where only the drip rate is required and the stand stays still. It is a poorer fit for wards where patients move around or where staff need to rely on the reading without confirming it visually. As the method yields only an estimate of the remaining fluid, newer studies rarely use it by itself.

### B. Gravimetric Load Cell Based Methods

Weight-based approaches are the most common way of tracking the level of IV fluid [1][3][4]. In contrast to drip counting, they use a small weighing sensor that measures the weight of the whole fluid bottle instead of counting single drops. As the medicine flows into the vein the bottle gets lighter, and the sensor passes a tiny signal to an amplifier module. The controller reads this value and turns it into a clear percentage of the liquid left. Because the method never touches the liquid, it is clean and safe.

Ravi Sankar et al. built a system from a weighing sensor and a small controller that sends its data to a phone application, and they reported an accuracy of 98.7 percent [1]. Pandian et al. employed two weighing sensors so that two beds could be observed together. Their error remained under 5 percent, and the system issued warnings at three levels as the bottle grew emptier [3]. Abiodun et al. likewise used a weighing sensor and added secure data transfer to keep patient details protected [4]. Their warning levels were fixed at half of the bottle and close to the end of the bottle.

Movement is the chief weakness of weight-based methods. A shaking bed or a patient tugging on the tube can make the reading jump. The sensor also needs firm support and periodic adjustment. Empty bottles differ in weight from product to product, so the starting value has to be set correctly every time. In addition, a weighing system cannot detect blood or air inside the tube.

Weight-based methods suit the core job of telling the nurse when a bottle needs replacing. Their advantage is that the reading is unaffected by the color or thickness of the fluid. This is why most of the newer studies build their systems on them. They are normally paired with an alert method, such as a buzzer or a phone message, so that the reading gets to the nurse in good time.

### C. Optical Backflow Detection Methods

Optical backflow methods for IV safety rely on measuring the light and color that pass through the lower part of the infusion tube [2]. A weighing sensor has no way of knowing whether blood has entered the tube. Some researchers therefore mount a color sensor on the outside of the tube, close to the patient. Clear fluid and blood take in light in very different ways, so when red blood flows back from the vein into the tube, the color the sensor sees changes. This change can be picked up without touching the liquid.

Enjeli et al. clipped a color sensor onto the tube and displayed the result on a web page. Their system identified the backflow correctly in all 50 trials and raised an alert in roughly two seconds [2]. A small clip keeps the sensor fixed in place on the tube. The main weakness of this approach is that strong room light or sunlight falling on the clear tube can alter the reading. It also gives no information about how much fluid is left in the bottle, so a system that only watches the tube color might warn about blood and yet miss an empty bottle.

Color sensing is a good example of a method that answers a single question extremely well: it quickly shows whether blood has got into the tube. It is not intended to measure the fluid level or to detect air. A color sensor is therefore normally treated as one part of a larger system and not as a complete solution. Its use also depends on the tube type, since very dark or tinted tubes can conceal the color change.

### D. Ultrasonic Air Bubble Detection Methods

Air in the tube is one of the gravest hazards of an infusion, and sound-based sensors are one means of detecting it. A pair of sensors is fitted on opposite sides of the tube. One sends out a tiny sound pulse and the other receives it. Sound moves differently through liquid than through air, so when an air bubble passes between the two sides the received signal changes and the system can sound an alarm. These sensors operate from outside the tube and never come into contact with the medicine.

Wang et al. studied a sensor built from tiny sound-wave components for observing infusion drips [13]. Sound-based sensors are known to cope with colored or cloudy fluids better than simple light sensors, because they do not depend on how transparent the liquid is. Their drawback is that they call for more complex circuits and more power than simple sensors. They also need good contact with the tube to give stable readings.

The main strength of sound-based sensing is that it works from outside the tube and with many types of fluid. The difficulty lies in the extra circuit work and the need for steady contact with the tube. Studies on very small sound-based components, such as that of Wang et al., indicate that the size and power demand of these sensors are shrinking [13].

### E. Capacitive Sensing Based Methods

The bubble detection methods in this section make use of the general electrical property known as capacitance. Kok et


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al. showed that two thin metal strips wrapped around the outside of the tube can sense the difference between liquid and air, since the two affect an electric field differently [5]. The reading stays steady without any contact with the sterile medicine inside. Their sensor could detect bubbles as small as 35 microliters.

The sensor of Kok et al. consumed very little power and used very cheap parts [5]. It was wired straight to the touch pins of a common controller, which kept the circuit simple. The weakness of this approach is that it responds to nearby touch and to electrical noise, and it needs careful adjustment for each tube and fluid. Thick or colloidal medicines can also change the reading.

Capacitive sensing appeals because of its low cost and low power use. It is a sensible choice where many beds must be covered on small budgets. The need for careful adjustment is the main reason that further tests with different tubes and fluids are still needed before it can be trusted in everyday hospital use.

### *F. GSM and SMS Alert Based Methods*

The bedside sensing methods described above rely on local buzzers to warn people nearby, or on a small screen to show fluid levels. A more flexible way to reach nurses who are walking in other wards is the mobile phone link introduced by Kabir et al. [6]. In this approach a SIM card module is attached to the main controller at the patient's bed. The weight of the fluid is compared continuously against preset safety limits. A buzzer sounds when the bottle is 15 percent full, and a text message is sent at 10 percent.

This cellular link is what lets the system cover a wide area without needing the hospital network. The nurse gets a text message directly on a personal phone. The drawback is that messages may be delayed when the mobile network is congested, and the running cost of the messages has to be considered when there are many beds [6][7].

Mobile phone alerts are most helpful when the nurse is away from the ward and the hospital network cannot be relied upon. Staff also accept them easily, since a text message needs no special training. The limitations are the message cost and the possible delay on a congested network. For these reasons, phone alerts are frequently combined with a local buzzer at the bed.

### *G. Cloud and Mobile Dashboard Based Methods*

Cloud-based methods deal with the task of watching many IV bottles across an entire ward simultaneously. A buzzer at the bedside cannot show fluid trends to a doctor seated in a central office. This need has led researchers to adopt a Wi-Fi approach, in which a small controller sends live readings to internet services that present the data on a phone or computer screen [1][3][4].

Ravi Sankar et al. built a phone dashboard that tracks the fluid weight and alerts the user when the liquid runs low [1]. Pandian et al. used a database service together with a phone application that gave spoken and written alerts [3]. Enjeli et al. created a web dashboard that shows backflow alerts in real time [2]. In a different approach, Abiodun et al. took data security into account and connected their controller to web services for secure alerts by message and email [4]. With such records, nurses can compare fluid levels across many beds from a single desk.

These dashboards, however, rely entirely on a working hospital Wi-Fi network. If the network goes down, the alerts may stop and the nurse may remain unaware of a problem. Sreekumar et al. reviewed more than 28 systems and observed that the reliability of wireless links is a common concern [7].

Cloud-based methods have made it far easier to see the state of many bottles together. They also store a record that doctors can consult later. Their main weakness is their dependence on the network and on an outside service. A hospital choosing such a system has to be certain that its network is strong enough and that patient data is handled safely.

### *H. Automated Tube Clamping Approach*

IV safety control can be viewed as a two-state problem: the infusion tube must stay open during normal dripping and must be closed before the bottle runs dry. Mechanical actuators offer a direct physical answer. By combining weight sensors with electric valves, researchers have developed automatic reverse flow blocking systems [6]. The two states are normal flow, while the bottle weight is above the safe mark, and blocked flow, once the weight reaches a critical low mark.

Kabir et al. used a small electric valve that pinches the tube. It alerted the nurse with a buzzer at 15 percent and sent a text at 10 percent, and then it shut the tube at 7 percent [6]. Other designs use a small motor that presses the tube gradually, which lets the flow be adjusted as well as stopped [10]. Most studies in this area still depend on alerts alone and do not stop the flow. The valves also draw a fair amount of power, which is a problem for battery-powered units [6][7]. A stopping device has to be safe in its own right as well: it must not damage the tube, and it must not close by mistake during a normal infusion.

Stopping the flow automatically is the most direct way to protect a patient when no nurse is nearby. It is also the least common feature among the studies reviewed here. The reasons are the added cost, the power requirement and the care needed to make sure the tube is not damaged. Where the feature is present, it is usually joined with several warning levels so that a nurse has the first chance to act.

### *I. Integrated and Ward-Level IoT Based Methods*

This section covers approaches that go beyond one sensor at one bed. Some studies watch several beds at once. Some add signals from the patient's body. Others focus on how the wards are linked together or on how to keep the readings steady.

#### *1) Dual Bed Monitoring Approach*

This approach treats IV monitoring as a shared tracking arrangement in order to cut the hardware cost for each bed [3]. Two separate weighing sensors are connected to one controller board, and their inputs are handled one after the other so that two bottles can be watched at the same time. The aim is a practical model of IV tracking that is simple, cheap and accurate in crowded wards.

Pandian et al. used colored lights at the bed along with spoken alerts on a phone [3]. The error stayed under 5 percent


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in their tests. The system was still a prototype and had no means of stopping the flow. Their results suggest that sharing one controller between two beds can bring the cost down.

*2) Monitoring Using Patient Vital Features*

A classical IV monitor checks only the weight of the bottle, but some authors have introduced health monitoring systems that add sensors for the patient's body. Yeri and Patil measured pulse, body temperature and oxygen level and sent the values to a web page [8]. Valsalan et al. combined body signals with room conditions and applied simple rules to decide whether the person was well or unwell [9].

Such systems are valuable for general care, because doctors can tell from one screen whether a patient is developing a fever or a rapid heartbeat. They do not observe the fluid or the tube, however, so they cannot warn about an empty bottle or air in the line. They demonstrate that a patient can be monitored remotely with low-cost parts, and that infusion safety is a separate problem requiring its own sensors.

*3) Automated Roller Clamp Approaches*

Valves and motor-driven pinchers are the most common mechanical ways of controlling flow [6][7][10]. In some studies a small motor is used to turn the ordinary roller clamp found on a standard IV set. A design of this kind aims for smooth speed adjustment and complete closing of the tube without harming the plastic.

Arfan et al. described a device that monitors and controls the infusion rate with attention to portability [10]. The chief advantage of motor-based control over a plain on-off valve is that the drip rate can be changed in small steps. The chief disadvantage is the additional parts and power needed. Sreekumar et al. noted that actuation for safety appears in only a small share of the systems they reviewed [7].

*4) Local Wireless Link Approach*

In hospital wards, it helps to have a wireless alert method that internet outages and router failures cannot disturb. Researchers have looked at direct device-to-device radio links that need no router. Mutiara et al. tested one such link and examined how well it performs in real use [12]. These links can carry short warning messages between the bedside units and a display at the nursing desk. The benefit of a local link is that alerts can still get through when the hospital network is busy or down. Its limits are the short range of every device and the need to position the devices so that they can reach one another. Sreekumar et al. also listed wireless reliability among the main concerns of the field [7]. The choice of link depends on the building and on how many beds have to be covered.

*5) Low Power Operation Approach*

As portable medical electronics become more widespread, researchers are looking into low-power designs for IV monitors fixed to rolling drip stands [5][6]. A small battery makes life hard for power-hungry parts such as always-on mobile phone modules and valves. Kok et al. demonstrated that a bubble sensor can run on just a few thousandths of a watt [5]. Valve-based systems need extra power at the moment the valve closes [6].

A portable device also has to be light and compact, and it should not get in the way of the patient or the nurse. Arfan et al. aimed for a portable device for precision care [10]. Portability and safety are not always easy to achieve together, because additional parts add weight and draw more power.

*6) Signal Filtering Based Approach*

The biggest problem in weight-based IV monitoring is false alarms, which arise when patients tug the tube or staff knock the stand. Sensor readings are never perfectly smooth, and small shakes and electrical noise can create sudden spikes. Punwatkar et al. applied simple filtering steps to remove abrupt jumps and smooth the readings of an infusion monitor [11].

Rather than relying on one raw reading, these steps take several readings and produce a steadier value, which makes the alerts more trustworthy. Too much smoothing, though, can slow the response to a genuine emergency, so a good system has to balance quick reaction against steady readings. False alarms are a serious matter because staff may start to ignore a device that warns too often.

*7) Alert Level and Display Design*

Many studies use more than one warning level. The first tells the nurse that the bottle will soon need replacing, and a second, stronger one signals that the matter is urgent. Pandian et al. used three levels as the bottle became emptier [3]. Kabir et al. used a buzzer first and then a text message [6]. Abiodun et al. set one warning level at half of the bottle and a critical level near the end [4].

How an alert is presented also matters. Ravi Sankar et al. used a small local display together with a phone application [1]. Enjeli et al. built a web page showing the state of the tube [2]. Pandian et al. also sent spoken and written messages to a phone [3]. A nurse moving between beds may notice a sound sooner than a screen, so the best design is usually one that reaches the nurse in more than one way. Stored records can help hospital staff follow how a treatment went and find the time at which a problem began. Very few of the reviewed studies discuss how records are kept when the network is unavailable, and this remains a practical question for hospital use.

*8) Cost and Hygiene Considerations*

Cost determines whether a device actually reaches a patient's bed. An inexpensive device can be installed at every bed in a ward, while an expensive one may be reserved for the most serious cases. Kok et al. showed that a bubble sensor can be made at a very small cost [5]. Ravi Sankar et al. and Pandian et al. used common low-cost parts for weight measurement [1][3]. The overall cost covers more than the sensor, since the display, the wireless link, the power supply and the housing all add to the price.

A device kept near a patient also has to be easy to clean. Sensors mounted outside the tube have an edge here, as they never touch the fluid. The weighing, color and bubble sensors in the reviewed studies are all positioned on the outside of the bottle or the tube [2][3][5]. This leaves the fluid path untouched and lowers the risk of infection.

*9) Privacy and Safety Rules*

Monitoring devices that send data over a network deal with patient information, and that information must be kept


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private. Abiodun et al. paid attention to this point and used secure data transfer in their system [4]. Many of the other studies send data to a phone or web page without describing how it is protected [1][2][3]. A device should send only the information that is really needed, and only the right staff should be able to view it.

A device used on patients must also comply with the safety rules for medical equipment. These rules concern electrical safety and the influence of one device on another. Most of the reviewed studies describe prototypes and do not go into these rules in detail. This is understandable for early research, but it means more steps are required before any of these devices can be widely used in hospitals.

*10) Acceptance by Hospital Staff*

A device is only useful if nurses are willing to use it. Staff are busy and may not want to learn a complicated device, whereas a simple display and a clear alert sound make it easier to accept. The phone applications and web pages in the reviewed studies are a good step, since most people already know how to use a phone [1][2][3].

Staff must also be able to trust the alerts, and a device that frequently gives wrong warnings loses that trust quickly. Working closely with nurses while designing a device can help uncover problems early. Few of the reviewed studies report nurse feedback, so this is an area where more work can be done. Simple instructions and clear signals on the device itself make training easier and reduce the maintenance effort.

*11) Special Cases and Difficult Conditions*

Some patients need extra care during infusion. Children and elderly people have thin veins and small blood volumes, so a brief interruption of the flow or a small amount of air can matter more for them. Patients who receive thick medicines or blood products also create different conditions inside the tube, and a sensor that performs well with clear saline may react differently to such fluids. Most of the reviewed studies were tested with simple clear fluids, which limits what can be said about other cases.

Home care is another special case. A patient at home may have no trained person nearby and may sleep for long stretches. A monitoring device in this setting must be very easy to operate and must give family members a clear warning. The reviewed studies mostly target hospital wards and pay less attention to home use.

*12) Combined Monitoring Approaches*

A few studies attempt to carry out more than one task in a single device. Kabir et al. combined weight measurement with a warning stage and a stopping stage [6]. Arfan et al. combined drip rate watching with control of the flow [10]. Ravi Sankar et al. paired a local display with a phone application [1]. Such work shows that small devices can already perform several jobs together.

Even so, the combinations found in the literature are limited. Most of them watch one property of the infusion and add extra functions around it. Sreekumar et al. noted that a wider combination of sensing is seldom found in the units they examined [7]. This remains one of the points where further study is possible.

*13) Testing and Performance Measures*

The reviewed studies present their results in different ways. Some give the accuracy of the weight reading [1], some give the error as a percentage [3], and some give the time taken to deliver an alert [2]. Others report the smallest bubble that could be detected or the power drawn by the sensor [5]. This makes direct comparison hard, because a bubble sensor and a weighing system answer different questions and cannot be placed on the same scale.

Most tests are also short. A system may be checked for only a few minutes or for a small number of trials. Long tests with many bottles and many patients would give a better picture of how steady a device is. Reports that state the number of false alarms over a long period would also help hospital staff who have to decide whether to trust a device.

## III. CONCLUSION

This survey reviewed the main techniques for automatic intravenous fluid monitoring and patient safety. Early drip counting systems cut down manual checking, but they had trouble when the stand tilted or when drops gathered on the chamber wall. Weighing sensors, color sensing and bubble sensors have each made it easier to follow the fluid level and to detect blood or air. Phone alerts and web dashboards have made it easier to inform the nurse, and a few studies have gone further and tried to stop the flow automatically. Recent studies point to several clear developments. Researchers are working to lower the price of each part while keeping useful accuracy [5]. Web pages and phone applications are being used to present the data simply [1][2][3]. Attention is being given to secure data transfer so that patient details remain protected [4]. There is interest in device-to-device links that need no router [12] and in tiny sound-wave-based sensors for drip watching [13]. Filtering is also being applied to make readings steadier [11]. Taken together, these developments show the field moving from simple alarms toward systems that are more dependable and better suited to real hospitals.

The results of the reviewed studies underline how much cost and simplicity matter. The low-cost bubble sensor and the phone-based displays show that useful devices can be built on small budgets. This is significant because many hospitals cannot afford expensive equipment for every bed, and a cheap, simple device is more likely to reach the patients who need it.

From a practical standpoint, the best method depends on the setting. A small clinic may need only a low-cost weighing device with a local alarm. A busy ward may need alerts that reach staff in other rooms. A unit treating very ill patients may need additional safety actions. The literature supplies building blocks for each of these settings, but few complete solutions that have been proved in daily use.

The reviewed methods fall into a few clear groups. Drip counting gives the speed of the flow but depends on exact placement. Weight-based methods are accurate and easy to use, but they cannot detect blood or air in the tube. Color-based methods find blood quickly, but room light can disturb them. Bubble sensors guard against air but say nothing about the fluid level. Valve-based methods stop the flow on their own, but they are few in number and consume more power. Wi-Fi-based alerts are simple but depend on the network.


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Mobile network alerts do not need the hospital network, but they can arrive late. Health monitoring systems give useful body readings but leave the infusion unwatched. No single method solves every infusion monitoring problem.

Several challenges remain. Many systems depend on a single network, and a large number of studies only raise an alarm and cannot stop the flow if the nurse is far away. A system that watches just one thing can miss the others. Room light and electrical noise can disturb the sensors, and patient movement can change the weight reading. Different fluids can alter how the sensors behave. Battery life and cost are concerns for portable units. Finally, most studies were tested on a table as small prototypes, and very few have been tried in real wards.

Future work can be aimed at testing in real hospital wards and at better handling of movement. Devices that use less power and work well with many kinds of fluids and tubes are also needed. Alert methods that keep working when the hospital network is unavailable deserve more attention. Common test procedures and long-duration tests would allow different studies to be compared fairly, and close cooperation between engineers and nurses can help produce devices that fit the daily routine of the ward.

Another point that emerges from the literature is the need for steady and open reporting. Researchers who describe their test setup and results in plain detail make it easier for others to repeat and improve their work. Reports stating the number of trials, the kind of fluid and the room conditions are especially helpful. Such reporting would also help hospitals compare devices and pick the one that suits their needs.

Progress in this field is likely to come from steady, careful work and not from a single large step. Small improvements in sensors, alert methods and testing add up over time. This kind of open and careful research is especially valuable in a field where patient safety is at stake. The reviewed studies have laid a good base, and the next steps lie in real ward trials and in close work with nurses and doctors.

The review shows that most existing systems address only one part of the problem. Network failure, false alarms and missing safety actions remain open concerns, and more tests in real hospital wards are needed for further progress. Smart infusion monitoring therefore remains an active area with strong promise for patient safety.

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