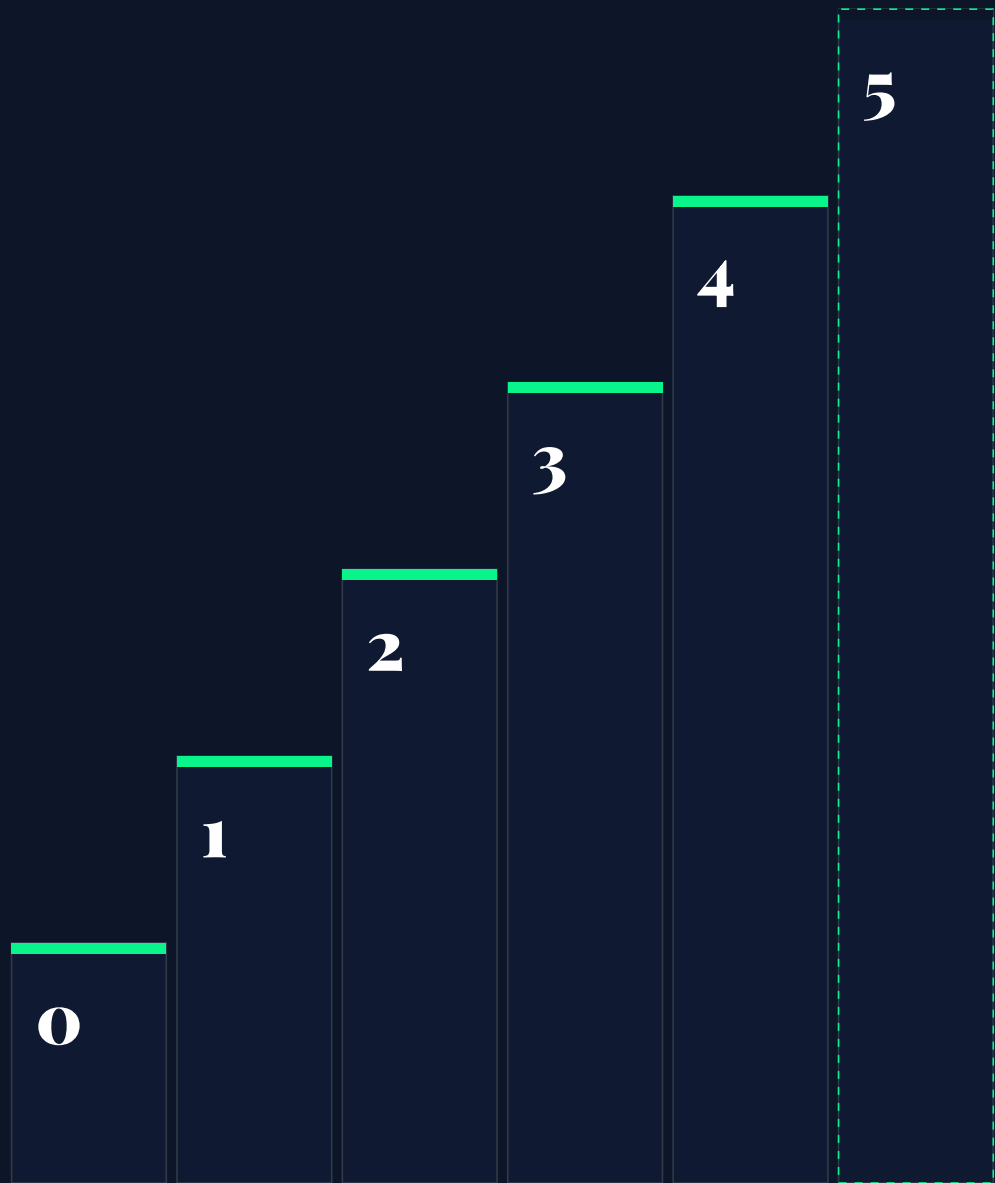

The Surgical Autonomy Ladder

A complete guide to the six levels of autonomy
in surgical robotics, and how to classify any claim.



Edition: October 11, 2026

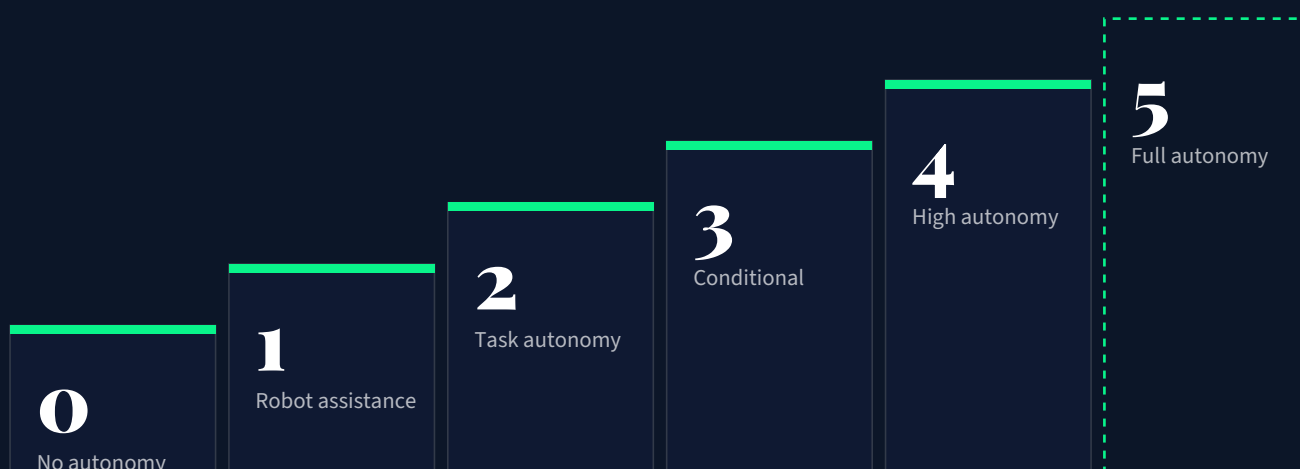
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Read this first

Every surgical robot is marketed with words like smart, intelligent, and autonomous.

Those words describe very different machines, from a console that copies a hand to a system that plans and acts without a person.

The Surgical Autonomy Ladder gives the difference a number, from Level 0 to Level 5, so that any claim can be placed on the same scale.



The rule behind everything in this guide

Classify the demonstrated task, not the marketing claim. A level belongs to what a system was shown doing, in a stated setting, with a stated amount of human involvement.

Five facts to carry away

- The six levels trace to a 2017 editorial in Science Robotics by Guang-Zhong Yang and colleagues, published March 15, 2017.
- The guide uses an editorial reading of that framework. It is not an official or universal classification.
- Level 0 and Level 1 describe the operating rooms people know. The surgeon plans and the surgeon drives.
- Levels 3 and above appear in research papers. The sources reviewed for this guide describe them on porcine tissue and in live animal studies.
- No Level 5 demonstration appears in the sources reviewed. Fully autonomous surgery in a human patient is not documented there.

Why a ladder

A ladder works because it forces one question: who is doing what?

Autonomy is not a feature that a robot has or lacks. It is a split of responsibility between a person and a machine, and that split changes from task to task.

A single system can sit on several rungs at once. A platform may steady a surgeon's hand during dissection and carry out a pre-planned step in another part of the same case.

For that reason, the guide rates tasks, not products.

Where the idea came from

The automotive industry gave the field its model. Self-driving cars were sorted into numbered levels so that regulators, buyers, and engineers could use the same words.

In 2017 a group of medical robotics researchers proposed the same move for medicine, with levels running from 0 (no autonomy) to 5 (full autonomy, no human needed).

They also argued that regulatory, ethical, and legal questions grow as human oversight shrinks and robot decision making grows.

Who benefits from using it

- Residents and surgeons gain a plain way to judge what a new platform really does.
- Hospital teams and buyers gain a checklist for separating demonstration from deployment.
- Readers of the news gain a way to size a headline that says a robot operated by itself.
- Researchers and engineers gain shared vocabulary for describing their own results.

The ladder at a glance

Read the table from the bottom up. Each rung moves one more job from the surgeon to the system.

Level	Name	Who decides	Who acts	Typical form
0	No autonomy	Surgeon	Surgeon, through the robot	Teleoperation. The robot copies hand motions.
1	Robot assistance	Surgeon	Surgeon, with guidance	Tremor filtering, motion limits, boundaries.
2	Task autonomy	Surgeon sets the task	Robot, for that task	A defined step runs on its own, under supervision.
3	Conditional autonomy	System proposes, surgeon approves	Robot	A strategy is generated, approved, and carried out.
4	High autonomy	System	Robot, supervised	The system makes decisions and the surgeon may intervene.
5	Full autonomy	System	Robot	No human is needed. Not documented in the sources reviewed.

How to read the numbers

The levels are ordered by how much human involvement remains, not by how impressive a demonstration looks. A flawless Level 0 procedure on a humanoid robot is still Level 0.

Two ideas that keep the ladder honest

- Decision and motion are separate. A system can move on its own while a person still makes every decision, and the reverse.
- Supervision does not equal autonomy. Watching a robot that is acting is a different job from performing the task, and the level depends on who carries the responsibility.

The six levels

0 No autonomy

The surgeon controls every motion, and the robot reproduces the commands exactly.

The surgeon	The system
Plans the operation, makes each decision, and drives every instrument movement from the console.	Translates hand movements into instrument movements, with scaling and a three dimensional view.

How to spot it

Look for a master and follower arrangement in which nothing moves unless the operator moves it.

A common overclaim

Calling a system intelligent or advanced because the image or the instrument is sophisticated. Better optics and more wrist freedom do not move a system up the ladder.

What it looks like

Teleoperated platforms, including the humanoid robots in the 2026 Nature feasibility study described on page 11.

1 Robot assistance

The surgeon still performs the task, while the system helps with precision or safety.

The surgeon	The system
Plans the case, makes the decisions, and performs the motions.	Filters tremor, holds a boundary, or offers guidance that the surgeon can follow or ignore.

How to spot it

Look for features that constrain or steady a movement but never start one on their own.

A common overclaim

Describing guidance as autonomy. A boundary that stops a tool is a safety aid, and the human still chooses where the tool goes.

What it looks like

Motion scaling with tremor filtering, haptic or virtual boundaries, and image overlays that guide the hand.

2 Task autonomy

The robot carries out one specific task that the surgeon has defined, while a person supervises.

The surgeon	The system
Chooses the task, sets its limits, supervises continuously, and can stop it.	Executes the defined task, such as a planned cut or a repeated step, without moment to moment commands.

How to spot it

Look for a narrow task with a clear start, a clear end, and a person who initiates it.

A common overclaim

Stretching one autonomous step into a claim about a whole procedure. Task autonomy covers the task, not the operation around it.

What it looks like

A pre-planned preparation step, a repeated harvesting motion, or an assistive task such as holding or retracting tissue on its own.

3 Conditional autonomy

The system builds a plan, the surgeon approves it, and the robot carries it out with a person ready to take over.

The surgeon	The system
Reviews and approves the strategy, watches the execution, and takes over when conditions change.	Generates a strategy from imaging or learned behaviour and performs the steps within an approved plan.

How to spot it

Look for a moment where the system proposes and a person accepts, followed by long stretches of execution without commands.

A common overclaim

Presenting a laboratory result as a clinical capability. At this level, the sources reviewed describe porcine tissue or live animal studies.

What it looks like

Autonomous suturing of bowel in a live pig (2022), and a learned multi-step phase of gallbladder removal on ex vivo tissue (2025), both on page 10.

4 High autonomy

The system makes surgical decisions and acts on them, and the surgeon is a supervisor who can intervene.

The surgeon	The system
Monitors, remains accountable, and can interrupt the procedure.	Chooses between options, plans, and executes, including responses to unexpected events.

How to spot it

Look for a system that handles variation and complications by itself across a whole phase or procedure.

A common overclaim

Using the word autonomous for a system that still depends on a person to choose each strategy. That is Level 3 at most.

What it looks like

A research goal. The sources reviewed for this guide document no system of this kind in routine use.

5 Full autonomy

No human is needed. The system plans, decides, performs, and manages complications alone.

The surgeon	The system
Is not part of the procedure.	Carries sole responsibility for planning, execution, and every unexpected event.

How to spot it

Look for a procedure completed end to end with no operator and no supervisor.

A common overclaim

Any claim of full autonomy should be treated as unproven until a primary source shows the procedure, the setting, and the absence of human input.

What it looks like

No Level 5 demonstration appears in the sources reviewed. Yang and colleagues identify this level as the point where regulatory and legal questions are hardest.

How to classify anything

Four questions place almost any system on the ladder.

Question	What the answer reveals
1. Who chose the plan?	If the system proposes and a person approves, the level is 3 or higher. If the person plans, the level is 2 or lower.
2. Who performed the motion?	If a person produced every movement, the level is 0 or 1. If the robot moved on its own, the level is 2 or higher.
3. Who watched and could stop it?	A supervisor who must stay engaged separates Levels 2 to 4 from Level 5.
4. What happened when something unexpected occurred?	A person stepping in marks Level 3 or lower. The system recovering alone marks Level 4 or higher.

The demonstrated task rule

The task in the question is the task that was shown, and not the task that a brochure implies.

If a video shows a robot placing clips and cutting during one phase of an operation, the guide rates that phase.

If the same system is described as capable of performing surgery, the guide still rates the phase, and records the rest as an aspiration.

A quick test

Replace the word autonomous in any claim with the specific task and the specific setting. If the sentence no longer sounds impressive, the claim was carrying more weight than the evidence.

Rating a system across several tasks

List each task the system performs, rate each one separately, and report the range.

A platform with Level 1 guidance for most steps and one Level 2 task is a Level 1 to 2 platform, and the guide names the exception instead of averaging it away.

Evidence settings

A level answers how much autonomy. The setting answers where it was shown.

Both are needed. A Level 3 result on an ex vivo specimen and a Level 3 result in a human patient are very different statements.

Setting	What it proves	What it leaves open
Simulation	The method works in software.	Everything about physical tissue and instruments.
Phantom or model	The robot can handle a standardized object.	Real anatomy, variation, and tissue behaviour.
Ex vivo tissue	The system can handle real biological tissue.	Bleeding, breathing, perfusion, and motion in a living body.
In vivo animal	The system can work in a living body under laboratory conditions.	Human anatomy, disease, and clinical workflow.
Human patient	Feasibility or benefit in people, depending on the study design.	Long term outcomes and wider use, depending on the study.

The two axis habit

Every claim in this guide is written as a level plus a setting, for example Level 3, ex vivo.

A reader who adopts the same habit can compare very different news stories on a common basis.

Why the setting matters so much

Live tissue bleeds, moves with breathing, and varies between patients. A result obtained without those conditions is a valuable step, but it is a different claim from a result obtained with them.

Four case studies

Each case is rated by task and by setting, using only what the primary source reports.

Case 1: STAR, bowel anastomosis in a live pig

In 2022, the Smart Tissue Autonomous Robot, developed in the laboratory of Axel Krieger at Johns Hopkins University, performed a laparoscopic bowel anastomosis in a living pig, which the university described as the first autonomous robotic surgery on a live animal.

Later reporting from the same group notes that the system relied on specially marked tissue, a controlled setting, and a predetermined plan.

Editorial reading

Level 3, in vivo animal, one defined task

Why not higher: the plan was fixed in advance and the conditions were controlled, so the result does not show handling of unexpected variation.

Case 2: SRT-H, a gallbladder removal phase on ex vivo tissue

On July 9, 2025, Science Robotics published the SRT-H framework from Johns Hopkins University and Stanford University, built on language conditioned imitation learning.

The paper reports that the system completed the clipping and cutting phase of a cholecystectomy in eight unseen ex vivo porcine gallbladders with no human intervention, performing 17 tasks in each.

Editorial reading

Level 3, ex vivo tissue, one phase of one procedure

Why not higher: the work used ex vivo porcine tissue, so breathing, bleeding, and living anatomy were not tested.

Case 3: Sentire, multi task automation on a live animal

A team at The Chinese University of Hong Kong reported learned policies for assistive surgical tasks on the Sentire system, tested first on ex vivo animal tissue and then in a live animal trial across three tasks.

The paper in Science Robotics describes the tasks as assistive, such as supporting the operation with the robot's own instruments.

Editorial reading

Level 2, in vivo animal, three assistive tasks

Why Level 2: each task is narrow and assistive, and the surgeon remains the one performing and deciding on the operation.

Case 4: Humanoid robots in a preclinical cholecystectomy

On July 8, 2026, Nature published a feasibility study led from the University of California San Diego in which teleoperated humanoid robots completed preclinical cholecystectomies in large non primate mammals.

The study reports surgical precision comparable to existing teleoperated systems, in both a human and robot team and a robot and robot team.

Editorial reading

Level 0, in vivo animal, teleoperated

Why Level 0: a surgeon controlled the robots remotely. The result is a new kind of body for the same level of autonomy.

What the four cases teach

Impressive hardware and impressive autonomy are separate things. The Level 0 humanoid study is a breakthrough in access and form. The Level 3 studies are breakthroughs in decision making. Neither is a claim about the other.

The pattern across the cases

- Every Level 3 result in these cases was obtained in animals or on animal tissue.
- Autonomy has grown by phase, from a single suturing task to a multi step phase of an operation.
- Settings matter as much as levels, and each step toward a living patient reopens the hardest questions.

Claim decoder

Common phrases in robotics news and marketing, with the question each one should trigger.

The phrase	Ask this	Usually points to
AI powered	Does the AI choose or move anything, or does it only analyze images?	Level 0 or 1
Smart robot	Which specific task runs without commands?	Level 1 or 2
Autonomous	Which task, in which setting, with whose approval?	Level 2 or 3, if shown
Performed surgery by itself	Which phase, on what tissue, and was a person standing by?	A phase, not a procedure
Learned from surgeons	Does the system act on what it learned, or only recommend?	Training method, not a level
First of its kind	First in which setting and for which task?	A setting, not a level
Human in the loop	Does the human decide, approve, or only watch?	Level 2 to 4, by role
Remote surgery	Who controls the instruments from a distance?	Usually Level 0

A seven line checklist for any new system

- Name the task that was demonstrated.
- Name the setting: simulation, phantom, ex vivo, in vivo animal, or human.
- Name who made the plan, and who approved it.
- Name who performed the motions.
- Name who could stop the system, and whether anyone did.
- Name what went wrong or was unexpected, and how it was handled.
- Name the primary source, such as a peer reviewed paper or an official regulatory filing.

Glossary

Term	Meaning
Autonomy	The share of decisions and actions a system carries out without a person.
Teleoperation	Remote control of instruments by a person, with the robot reproducing the person's movements.
Task autonomy	A robot carrying out one defined task on its own while a person supervises.
Supervised autonomy	Autonomous execution with a person watching and able to intervene.
Imitation learning	Training a system from recorded demonstrations by experts.
Ex vivo	Performed on tissue removed from a body.
In vivo	Performed in a living body, in animals or people.
Preclinical	Research before testing in human patients.
Anastomosis	A surgical connection between two structures, such as two ends of bowel.
Cholecystectomy	Surgical removal of the gallbladder.
Human in the loop	A design in which a person takes part in decisions or approvals.
Phantom	A standardized physical model used to test a system.

Sources and limits

Primary sources

Yang GZ, Cambias J, Cleary K, Daimler E, Drake J, Dupont PE, Hata N, Kazanzides P, Martel S, Patel RV, Santos VJ, Taylor RH. Medical robotics: Regulatory, ethical, and legal considerations for increasing levels of autonomy. *Science Robotics*. March 15, 2017;2(4):eaam8638. doi:10.1126/scirobotics.aam8638.

Kim JW, Chen JT, Hansen P, Shi LX, Goldenberg A, Schmidgall S, Scheikl PM, Deguet A, et al. SRT-H: A hierarchical framework for autonomous surgery via language conditioned imitation learning. *Science Robotics*. July 9, 2025. Preprint: arXiv:2505.10251.

Saeidi H, Opfermann JD, Kam M, et al. Autonomous robotic laparoscopic surgery for intestinal anastomosis. *Science Robotics*. 2022;7(62). The Johns Hopkins University announcement of July 9, 2025 describes this work as the first autonomous robotic surgery on a live animal.

Surgical embodied intelligence for generalized task autonomy in laparoscopic robot-assisted surgery. *Science Robotics*. doi:10.1126/scirobotics.adt3093. Chinese University of Hong Kong.

Liang Z, et al. In vivo feasibility study of humanoid robots in surgery. *Nature*. July 8, 2026. University of California San Diego.

Limits of this guide

- The six level framework is an editorial reading. It adapts the 2017 proposal and is not an official, regulatory, or universal classification.
- Level ratings of individual studies are editorial judgments. Other readers may place the same study one rung higher or lower.
- The guide rates demonstrated tasks. It does not assess clinical safety, effectiveness, or regulatory status of any product.
- Statements that something is not documented refer to the sources reviewed for this edition, dated October 11, 2026, and are not claims that no such work exists anywhere.
- This guide is educational and is not medical or regulatory advice.

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The Autonomy Claims Report

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