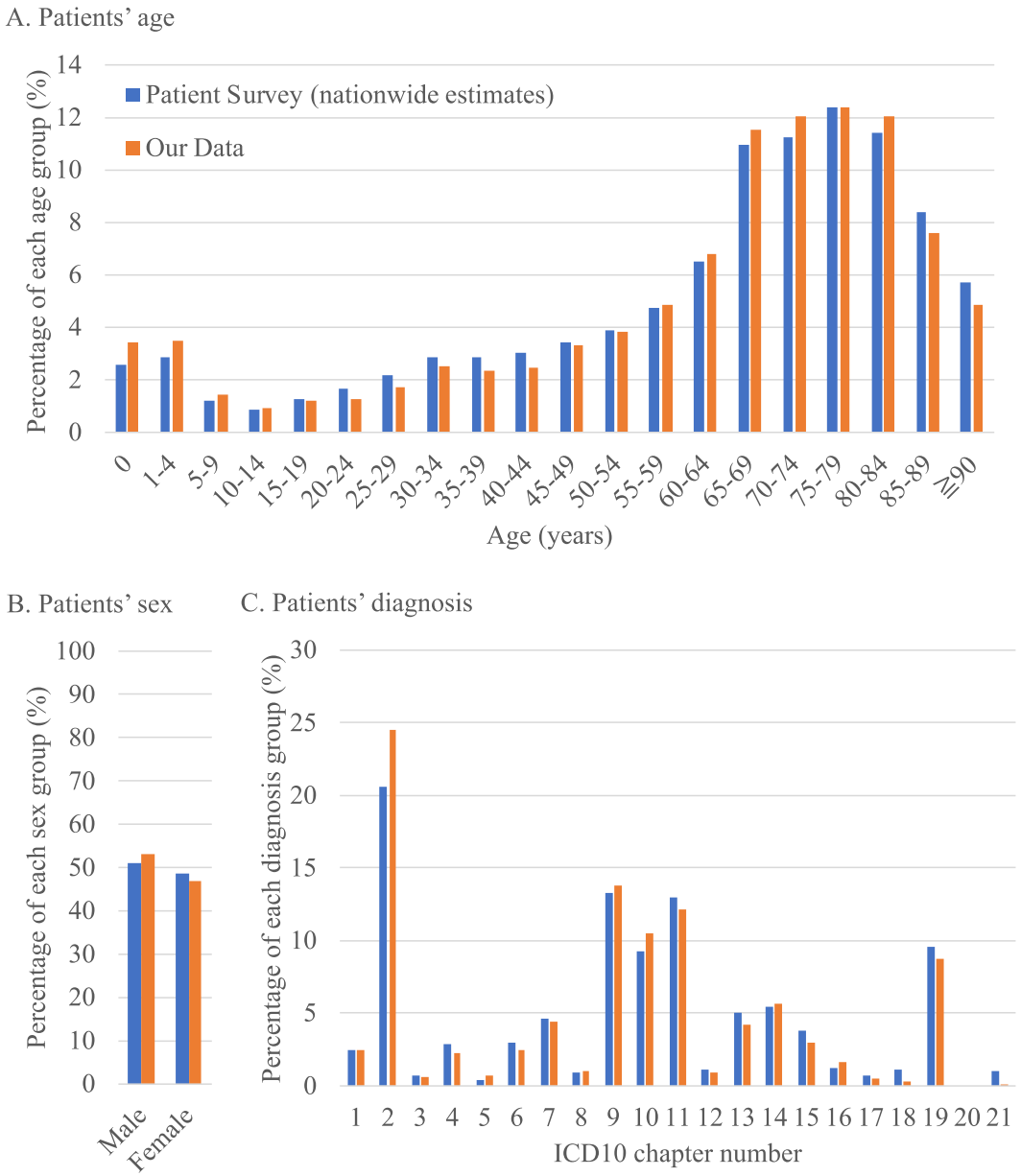
Appendices

Prevalence and Changes of Low-Value Care at Acute Care Hospitals: A Multi-Center Observational Study in Japan

Supplementary Figure 1. Comparison of discharged patients' characteristics between the Patient Survey (=nationwide representative survey) vs. the hospital claims data used in our study



The figure shows that the distributions of age, sex, and the principal diagnosis of patients discharged from acute care hospitals were similar between the nationwide estimates from the Patient Survey and those from the analytic hospitals in our data.

Supplementary Method 1. Quality controls of the database

The MDV claims database used in this study was collected in two steps. First, all the electronic claims data accumulated in target acute care hospitals are sent to the MDV after de-identification. Since electronic claims data are recorded for billing purposes in Japanese hospitals, all patients treated at a given hospital are included in the data. Then, they are imported into the database by data managers. Quality assessments of the data accuracy are performed as follows:

(a) Systematic errors during data registration at the hospital (e.g., errors due to changes in the in-hospital system) are checked and corrected after confirmation with the hospital.
(b) All claims data, including inpatient, outpatient, and prescription claims, are automatically investigated for abnormal values by comparing those to the previous month, the same month of the previous year. When an abnormal value is found, the data manager confirms it with the target hospital and request the hospital to resubmit the data if there is an error in the submitted data.
(c) Diagnosis and drug names are standardized into the International Classification of Diseases, Tenth Revision (ICD-10), and the Anatomical Therapeutic Chemical code using the master files. For disease names that have not been coded (freely described disease names), a uniquely developed matching dictionary between disease names and ICD-10 codes is applied and coded.

As for the completeness and accuracy of the MDV claims data, a study using physician medical record review as the gold standard in two hospitals participating in the MDV database reported that MDV claims data were able to identify cases of malignant tumors and severe infections with good positive predictive value and sensitivity.[1]

Supplementary Method 2. Identification of measurable low-value services

We first listed up 68 low-value services measured in previous seminal work in the US (Schwarz et al., 2015), Canada (Mcalister et al., 2018), and Australia (Badgery-Parker et al., 2019). Then, to identify low-value services not included in these studies and/or low-value services potentially unique to Japan, we conducted a literature review based on the candidates of low-value care picked up by the expert group in a predetermined process.

In this process, we began by assembling an specialist physicians board from as many clinical specialty areas as possible. The specialists were selected by the author group based on experience in their specialty, gender, and geographical location (by purposive sampling). We asked the selected specialists to review the clinical evidence to create a list of as many potentially low-value services as possible in their specialty area (allowing overlap) based on the peer-reviewed medical literature. The experts were also asked to judge the evidence level and categorized each service into the following three groups:
(1) Definitely low-value (there is evidence that it has no clinical benefit, namely the service has been concluded to be "having no effect" in multiple randomized controlled trials or meta-analyses.)
(2) Unclear (There is no evidence that it has clinical benefit, or evidence is mixed)
(3) Definitely effective (there is evidence that it has clinical benefit).
We contacted physicians in 31 specialties and finally obtained responses from physicians in 26 specialties (**Supplementary Table 1**). The specialists presented a total of 209 low-value services candidates.
Next, for each potentially low-value service listed by the specialists, physicians independent of the expert group (AM, RI, and KS in the author group) repeated the literature review and categorization process based on the clinical evidence in the same manner as described above.
Then, we selected those consistently categorized as "definitely low-value" by both specialists and independent physicians as low-value care. Among the 209 low-value medical candidates, 45 services were categorized as "definitely low-value" by specialists and independent physicians.

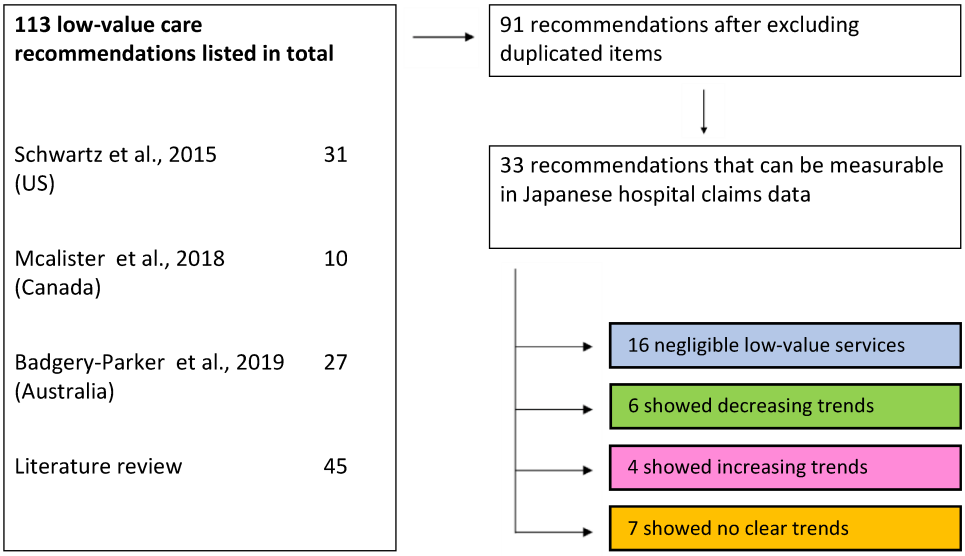
Finally, we combined the listed items from the seminal work and our literature review and identified 113 (68+45) recommendations. After we excluded duplicated recommendations, we selected low-value services measurable in the Japanese hospital claims data. Whether or not the service is measurable in claims data was determined by three physicians with sufficient experience in claims data analyses (AM, RI, and YT). The selection criteria were (1) being recorded in the hospital claims data under the Japanese health insurance system and (2) being possible to reasonably identify a low-value episode using the variables in the data with high specificity. Unmeasurable services included those for which there was insufficient information in the claims data to identify (e.g., head imaging for syncope and uncomplicated headache and back imaging for low back pain), and those that were not covered by Japanese public health insurance (services related to preventive care, pregnancy checkups, and regular deliveries, e.g., prostate cancer screening by prostate-specific antigen.

After excluding 22 duplicated recommendations and 58 unmeasurable recommendations, 33 services (**Supplementary Table 2**) were identified as measurable low-value services.

Supplementary Table 1. Clinical specialty areas of expert board

Specialty Area
Respiratory medicine
Gastroenterology
Cardiology
Nephrology
Primary care
Infectious disease
Hematology
Oncology
Endocrine disorders
Psychiatry
Preventive medicine
Digestive surgery
Breast surgery
Urology
Orthopedics
Ophthalmology
Otolaryngology
Anesthesiology
Intensive care
Emergency medicine
Pediatric surgery
Obstetrics and gynecology
Rehabilitation
Radiology
Pathology
Dermatology

Supplementary Figure 2. Overall summary of the study



Negligible low-value care was defined as the below-median number of low-value services (narrower definition) for the 33 services (see Table 1). Trends are determined by calculating the average annual percentage change.

Supplementary Table 2. Operational definitions of low-value care for each healthcare service

Healthcare services (recommendation sources)	Service denominator	Numerator	
		Broader low-value care definition (Base definition)	Narrower low-value care definition (Additional restrictions)
Antibiotics prescription for the common cold (literature review)	Any oral antibiotics prescription	Oral antibiotics prescription for patients with a diagnosis of common cold	No diagnosis of pneumonia, bacterial bronchitis, otitis media, peritonsillar abscess, croup and epiglottitis, streptococcus pharyngitis, or chronic pharyngitis No hospitalization in the same month
Serum T3 level testing for patients with hypothyroidism (Schwarz et al., 2015)	Any total or free T3 test	Total or free T3 measurement in a patient with a hypothyroidism diagnosis sometimes that calendar year	- [a]
Pregabalin prescription for back pain (literature review)	Any pregabalin prescription	Pregabalin prescription in a patient with the diagnosis of back pain	Pregabalin prescription in a patient with the diagnosis of back pain (except for patients with a diagnosis of fibromyalgia, diabetes, postherpetic neuralgia, arteriosclerosis, disc disorder, trigeminal neuralgia, or peripheral neuropathy)
Spinal injection for low back pain (Schwarz et al., 2015)	Any outpatient spinal injection in adults aged ≥ 18	Epidural (not indwelling), facet, or trigger point injections in a patient with a diagnosis of lower back pain in the same month, not associated with an inpatient stay (within 14 days)	No diagnoses indicating radiculopathy in the claim in the same month
Oral betamimetics prescription (literature review)	Any oral betamimetics prescription	Any oral betamimetics prescription	- [a]
Preoperative pulmonary function testing (PFT) (Schwarz et al., 2015)	Any outpatient PFT in adults aged ≥ 18	PFT occurring within 30 days prior to a low or intermediate-risk surgical procedure (selected surgeries [b])	No PFTs related to off-hour visits
Preoperative echocardiogram (Schwarz et al., 2015)	Any outpatient echocardiograms in adults aged ≥ 18	Echocardiogram occurring within 30 days prior to a low or intermediate risk non-cardiothoracic surgical procedure (selected surgeries [c])	No echocardiograms related to off-hour visits
Bone mineral density testing at frequent intervals (Schwarz et al., 2015; Mcalister et al., 2018)	Any bone mineral density test	Bone mineral density test less than two years after a prior bone mineral density test [d]	Only patients with a diagnosis of osteoporosis prior to the initial bone mineral density test
Hypercoagulability testing for patients with deep vein thrombosis (Schwarz et al., 2015; Mcalister et al., 2018)	Any lab tests for hypercoagulable states	Lab tests for hypercoagulable states within 30 days following the diagnosis of lower extremity deep vein thrombosis or pulmonary embolism	No evidence of recurrent thrombosis, defined by diagnosis of deep vein thrombosis or pulmonary embolism more than 90 days prior to claim
Intravenous betamimetics for inhibiting preterm labor, > 48h (literature review)	Any hospitalizations with intravenous betamimetics administration	Hospitalizations in which betamimetics intravenous infusion was administered for ≥ 3 days	- [a]
Preoperative stress testing or stress testing for stable coronary disease (Schwarz et al., 2015; Mcalister et al., 2018)	Any outpatient stress electrocardiogram, echocardiogram, nuclear medicine imaging, cardiac MRI, or CT angiography in adults aged ≥ 18	1) Stress test occurring within 30 days prior to a low or intermediate risk non-cardiothoracic surgical procedure (selected surgeries [b]) or 2) stress test in a patient with an established diagnosis of ischemic heart disease or angina (at least 6 months prior to the stress test)	Only patients with a diagnosis of myocardial infarction (ICD10: I21-I23) in order to exclude patients with a history of non-cardiac chest pain inaccurately coded as angina (i.e., those with no underlying ischemic heart disease who might benefit from screening and optimization of medical management)

		No stress test related to off-hour visits, which might be indicative of the acute coronary syndrome	
Preoperative breast MRI (literature review)	Any breast MRI in adults aged ≥ 18	Breast MRI within 30 days prior to breast cancer surgery [e]	Only patients with no diagnosis of hereditary breast and ovarian cancer syndrome and breast Paget's disease, no surgery for benign breast diseases within 3 months, and no diagnosis of breast cancer more than 12 months prior to the MRI (to include only primary breast cancer)
Intravenous sivelestat for acute respiratory disease syndrome (literature review)	Any hospitalizations with intravenous sivelestat administration	Any hospitalizations with intravenous sivelestat administration	- [a]
Traction therapy for back pain or neck pain (literature review)	Any traction therapy in adults aged ≥ 18	Traction therapy for a patient with a diagnosis related to back or neck pain.	Only patients without a diagnosis of malignant spinal tumor, rheumatoid arthritis, spondylitis, or osteoporosis.
Spinal fusion for lumbar stenosis ((Badgery-Parker et al., 2019; literature review)	Any hospitalizations with spinal fusion surgeries in adults aged ≥ 18	Spinal fusion surgeries for lumbar stenosis (identified in inpatient claims data)	Only patients without a diagnosis of spondylolisthesis, pain in the foot, radiculopathy, sciatica, or congenital malformations of the spine
Endoscopy for dyspepsia for people < 55 years or colonoscopy for constipation in people < 50 years (Badgery-Parker et al., 2019)	Any endoscopies (esophagogastroduodenoscopies and colonoscopies) in adults aged 18-54	1) Endoscopy in a person aged 18-54 with a diagnosis of dyspepsia or 2) colonoscopy in a person aged 18-49 with a diagnosis of constipation	1) Endoscopy in a person aged 18-54 with a diagnosis of dyspepsia and no diagnoses of dysphagia, anemia, weight loss, cancer of the digestive system or 2) colonoscopy in a person aged 18-49 with a diagnosis of constipation and no diagnoses of anemia, weight loss, cancer of the digestive system, or other diseases of the digestive system
PTH testing for patients with stage 1-3 chronic kidney disease (Schwarz et al., 2015)	Any PTH testing	PTH measurement in patients with chronic kidney disease, without dialysis services in any of the same FY claims	No hypercalcemia diagnosis in any of the same FY claims
Electroencephalography (EEG) for headache (Schwarz et al., 2015)	Any outpatient EEG	EEG with headache diagnosis in the claim	No epilepsy or convulsions in the claims
1, 25-dihydroxy vitamin D testing in the absence of hypercalcemia or decreased kidney function (Schwarz et al., 2015)	Any calcitriol testing in adults aged ≥ 18	Calcitriol testing for patients without hypercalcemia or secondary hyperparathyroidism was noted in the claim, and without a history of CKD	No diagnoses indicating non-PTH mediated hypercalcemia (sarcoidosis, tuberculosis, and selected neoplasms)
Vertebroplasty for osteoporotic vertebral fractures (Schwarz et al., 2015; Badgery-Parker et al., 2019)	Any vertebroplasty in adults aged ≥ 18	Vertebroplasty for vertebral fracture	No bone cancers, myeloma, or hemangioma were noted in the claim in the same month
Inferior vena cava (IVC) filters for the prevention of pulmonary embolism (Schwarz et al., 2015)	Any hospitalizations with IVC filter placement in adults aged ≥ 18	Hospitalizations with IVC filter placement in a patient with a diagnosis of deep vein thrombosis or pulmonary embolism	- [a]
Endotoxin apheresis for sepsis (literature review)	Any hospitalizations with endotoxin apheresis in adults aged ≥ 18	Hospitalizations with endotoxin apheresis	- [a]
Artificial liver support for acute liver failure (literature review)	Any hospitalizations with artificial liver support in adults aged ≥ 18	Hospitalizations with artificial liver support in a patient with a diagnosis of acute liver failure	Only hospitalizations without a diagnosis of chronic or subacute liver disease
Pulmonary artery catheterization (PAC) in the ICU (Schwarz et al., 2015)	Any hospitalizations with PAC in adults aged ≥ 18	PAC during an inpatient stay that involved an ICU but not surgical procedures	Exclude claims that involved pulmonary hypertension or cardiac tamponade

Arthroscopic surgery for knee osteoarthritis (Schwarz et al., 2015; Badgery-Parker et al., 2019; literature review)	Any arthroscopic debridement/chondroplasty of the knee in adults aged ≥ 18	Arthroscopic surgery of the knee with the diagnosis of osteoarthritis or chondromalacia in the claim	No meniscal tear noted in the claim
Renal angioplasty (Schwarz et al., 2015; Badgery-Parker et al., 2019; literature review)	Any renal angioplasty in adults aged ≥ 18	Any renal angioplasty	Only a patient with a diagnosis of renovascular hypertension or renal atherosclerosis, and no diagnosis of fibromuscular dysplasia of renal artery, in the claim
Percutaneous coronary intervention (PCI) with angioplasty or stent placement for stable coronary disease (Schwarz et al., 2015)	Any stent placement or balloon angioplasty in adults aged ≥ 18	Stent placement or balloon angioplasty for a patient with an established diagnosis of ischemic heart disease or angina (at least 6 months prior to the procedure) Procedure not associated with off-hour visit, which might be indicative of acute coronary syndrome Procedure not related to acute coronary syndrome	Only patients with a past diagnosis of myocardial infarction in order to exclude patients with a history of non-cardiac chest pain inaccurately coded as angina
Intravenous anti-herpes drugs for sudden sensorineural hearing loss (literature review)	Any hospitalizations with intravenous acyclovir administration	Hospitalizations with intravenous anti-herpes drugs administration for a patient with a diagnosis of sudden sensorineural hearing loss	Only patients without a diagnosis of herpes infections (herpes simplex virus or herpes zoster virus)
Surgery for vesicoureteral reflux (Badgery-Parker et al., 2019)	Any surgery for vesicoureteral reflux in children aged <12	Any surgery for vesicoureteral reflux	Only patients with vesicoureteral-reflux
Tricyclic antidepressants prescription for children without other psychological disorders (literature review)	Any tricyclic antidepressants prescription for children in children aged 6-18 years	Tricyclic antidepressants prescription for children with a diagnosis of depression	Tricyclic antidepressants prescription for children with a diagnosis of depression, and without other psychological disorders
Carotid endarterectomy in asymptomatic patients (Schwarz et al., 2015; Badgery-Parker et al., 2019)	Any carotid endarterectomy in adults aged ≥ 18	Carotid endarterectomy for a patient aged ≥ 75 without a diagnosis of stroke, transient ischemic attack TIA, retinal artery occlusion, or nervous and musculoskeletal symptoms. Exclude emergency admissions (identified in inpatient claims)	Only a patient with a history of acute myocardial infarction, chronic obstructive pulmonary disease, or alcohol related disorder, with dialysis services, with presence of cardiac pacemaker, or aged 90 or older (indicating high-risk patients)
Nasolacrimal probe in infants (Badgery-Parker et al., 2019)	Any nasolacrimal probe in infants aged <1 year	Probing of nasolacrimal duct in infant in infants aged <1 year	Probing of nasolacrimal duct in infant aged <1 year with diagnosis of inflammation, stenosis, insufficiency, or stricture of lacrimal passages, or other congenital malformation of lacrimal apparatus
Electroconvulsive therapy in children (Badgery-Parker et al., 2019)	Any electroconvulsive therapy in children aged 5-11 years	Any electroconvulsive therapy in children aged 5-11 years	Only children with a diagnosis of depression

[a] The narrower definition is set the same as the broader definition.

[b] Procedures include surgeries of the breast (K472-K476), colectomy (K719), cholecystectomy (K672), transurethral resection of the prostate (K841), hysterectomy(K872-K879), orthopedic surgeries including arthroscopy (besides hip and knee replacement) (K023-K144), corneal transplant (K259), cataract removal (K282), retinal detachment (K275, K276, K277, K279, K280, K281, K284), hernia repair (K633, K634), and lithotripsy (K768), CABG (K552), aneurysm repair (K560), thromboendarterectomy (K551, K609) PTCA(K546-K549), and pacemaker insertion (K597-K599).

[c] Procedures include surgeries included in footnote "a" except for CABG (K552), aneurysm repair (K560), thromboendarterectomy (K551, K609) PTCA(K546-K549), pacemaker insertion (K597-K599)

[d] By construction, we evaluated low-value care during the fiscal year 2017 through 2019.

[e] Since the reimbursement policy for this service was introduced in the fiscal year 2016, we evaluated low-value care during the fiscal year 2016 through 2019.

Supplementary Table 3. Codes for measures of low-value services

	Codes for identification	Healthcare spending calculation
Antibiotics prescription for the common cold	Anatomical Therapeutic Chemical (ATC) classification system code: J01xx ICD10: J00, J01, J028, J029, J041, J042, J06 (common cold); J12-J18 (pneumonia), J200, J201, J202 (bacterial bronchitis); H66 (otitis media); J36 (peritonsillar abscess); J05 (croup and epiglottitis); J020 (streptococcus pharyngitis); J312 (chronic pharyngitis)	a
Serum T3 level testing for patients with hypothyroidism	Reimbursement code: 160031310, 160033210 (T3 test) ICD10: E02, E03 (hypothyroidism)	a
Pregabalin prescription for back pain	Reimbursement code: 621983701, 621983801, 621983901, 622538201, 622538301, 622538401, 622827701, 622827901, 622834901, 622835001 (pregabalin) ICD10: M430, M431, M4329, M4646, M4649, M471, M4786, M4799, M4800, M4806, M4808, M4809, M510, M511, M512, M513, M518, M519, M5326, M5329, M533, M539, M5416–M5419, M543, M544, M545, M5489, M549, M961, M99, Q762, S33 (back pain); M797 (fibromyalgia); B022, G530 (postherpetic neuralgia); M50, M51 (disc disorder); G50 (trigeminal neuralgia); E10-E14 (diabetes); I70 (arteriosclerosis); T812, G54-G64 (peripheral neuropathy)	a
Spinal injection for low back pain	Reimbursement code: 150235510, 150236010, 150242110, 150266010, 150265010, 150235710, 150350710, 150236010, 150265710, 150351310, 150239110 ICD10: M430, M431, M4329, M4646, M4649, M471, M4786, M4799, M4800, M4806, M4808, M4809, M510, M511, M512, M513, M518, M519, M5326, M5329, M533, M539, M5416–M5419, M543, M544, M545, M5489, M549, M961, M99, Q762, S33 (back pain); M511, M5416-M5419 (radiculopathy)	All outpatient expenses occurring on the same day of service were included in healthcare spending estimates.
Oral betamimetics prescription	Reimbursement code: 610406047, 610461096, 620001965, 620003079, 620006607, 620564904, 620564905, 620564912, 620564913, 620564918, 620564921, 620565301, 620565302, 620006947 (oral betamimetics)	a
Preoperative pulmonary function testing (PFT)	Reimbursement code: 160062610, 160062710, 160062810, 160063010 (PFT); 111000570, 112001110, 112006470, 113016270, 113018570, 111000670, 112001210, 112006570, 113016370, 113018670, 111000770, 112001310, 112006670, 113016470, 113018770 (off-hour visit)	a
Preoperative echocardiogram	Reimbursement code: 160072510, 160072610 (echocardiogram); 111000570, 112001110, 112006470, 113016270, 113018570, 111000670, 112001210, 112006570, 113016370, 113018670, 111000770, 112001310, 112006670, 113016470, 113018770 (off-hour visit)	a
Bone mineral density testing at frequent intervals	Reimbursement code: 160091310, 160186870, 160147310, 160170410 (mineral density test) ICD10: M80, M81, M82 (osteoporosis)	a
Hypercoagulability testing for patients with deep vein thrombosis	Reimbursement code: 160154350, 160164050 (anticardiolipin antibodies), 160169150, 160197610 (lupus anticoagulant), 160192310, 160114110, 160192210, 160124850 (Protein C and S activity and antigen), 160016010 (factor V test) ICD10: I802 (deep vein thrombosis); I269 (pulmonary embolism)	a
Intravenous betamimetics for inhibiting preterm labor, >48h	Reimbursement code: 620002177, 620003459, 620004783, 620006201, 620006329, 620007547, 620569915, 620569916, 620570101, 620570202, 620336901 (betamimetics, intravenous rout)	a
Preoperative stress testing or stress testing for stable coronary disease	Reimbursement code; 160069210, 160069310, 160069410, 160069910, 160070050, 160198810, 170020070, 170027770, 170027870 (stress test); 111000570, 112001110, 112006470, 113016270, 113018570, 111000670, 112001210, 112006570, 113016370, 113018670, 111000770, 112001310, 112006670, 113016470, 113018770 (off-hour visit) ICD10: I20-I25 (ischemic heart disease or angina)	Including healthcare spendings for imaging and reading, and supplies such as contrast media.
Preoperative breast MRI	Reimbursement code: 170035170 (breast MRI); 150121610, 150303110, 150316510, 150262710, 150121710, 150121810, 150121910, 150386510, 150345870, 150345970 (breast cancer surgery); 150121410, 150405810, 150413710 (surgery for benign breast diseases)	Including healthcare spendings for MRI imaging and reading, and supplies such as contrast media.

	ICD10: C50 (breast cancer) (C5001 for breast Paget's disease); R798 (hereditary breast and ovarian cancer syndrome)	
Intravenous sivelestat for acute respiratory disease syndrome	Reimbursement code: 622381901, 622391901, 622393901, 622394601, 622401101, 640462009 (sivelestat)	a
Traction therapy for back pain or neck pain	Reimbursement code: 140048010 (traction therapy) ICD10: M430, M431, M4329, M4646, M4649, M471, M4786, M4799, M4800, M4806, M4808, M4809, M510, M511, M512, M513, M518, M519, M5326, M5329, M533, M539, M5411, M5416–M5419, M543, M544, M545, M5489, M549, M961, M99, Q762, S33 (back pain); M50, M540, M5411, M542 (neck pain); C412 (malignant spinal tumor); M05, M06, M790 (rheumatoid arthritis); M45, M46 (spondylitis); M80, M81, M82 (osteoporosis)	a
Spinal fusion for lumber stenosis	Reimbursement code: 150314810, 150282510, 150282610, 150314610, 150314710, 150368870, 150368970, 150369070, 150314810, 150369170, 150369370, 150369170, 150397210, 150314210 (spinal fusion) ICD10: M4806 (lumber stenosis); "M431 (spondylolisthesis); M796 (pain in foot); M511, M5416-M5419 (radiculopathy); M543, M544 (sciatica); Q76 (congenital malformations of spine)	The additional healthcare spending (including the healthcare spending of materials) compared to the healthcare spending of laminectomy was used as an estimate of the healthcare spending.
Endoscopy for dyspepsia for people < 55 years or colonoscopy for constipation in people < 50 years	Reimbursement code: 160093810 (esophagogastroduodenoscopy), 160094710, 160094810, 160094910, 160202750 (colonoscopy) F453, K30, R101 (dyspepsia) K589, K590 (constipation); D50-53, D55-64 (anemia), R131 (dysphagia), R634, R64 (weight loss); C15-26, C784-788 (cancer of digestive system), K20-K31, K35-K38, K40-K44, K50-K52, K55-K64 (except for K589 and K560), K65-K67, K70-K77, K80-K87, K90-K93 (other diseases of the digestive system);	All expenses incurred on the same day of service were included in healthcare spending estimates.
PTH testing for patients with stage 1-3 chronic kidney disease	Reimbursement code: 160035510 (PTH test); 140036710, 140051010, 140051110, 140057810, 140057910, 140058010, 140059310, 140059410, 140060210, 140060310, 140060410, 140059070, 140059170, 140052810, 140058110, 140058210, 140058410, 140058510, 140058610, 140007710, 140008170, 140052570, 140052970, 140007910, 140058770, 140058870, 140033770, 140058970, 140055970, 140029850, 140053670 (dialysis). ICD10: N181, N182, N183 (chronic kidney disease); E8352 (hypercalcemia)	a
Electroencephalography (EEG) for headache	Reimbursement code: 160075310, 160075750, 160075850, 160075950, 160076050, 160200510, 160170610, 160207510, 160187010 (EEG) ICD10: G43, G44 (headache); A080, A081, A084, F445, G253, G40, G41, G433, G513, G934, R56 (epilepsy or convulsions)	a
1, 25-dihydroxyvitamin D testing in the absence of hypercalcemia or decreased kidney function	Reimbursement code: 160158150 ICD10: N181, N182, N183 (CKD); E8352 (hypercalcemia); E211 (secondary hyperparathyroidism); D86 (sarcoidosis); J65, A15-A19, B90 (tuberculosis); C43, C44, C50, C56, C64, C65, C67, C81-C86, C88, C90-C96 (selected neoplasms)	a
Vertebroplasty for osteoporotic vertebral fractures	Reimbursement code: 150355210 (vertebroplasty) ICD10: M8008, M8018, M8028, M8038, M8048, M8058, M8088, M8098, M48.4, M84.4, S12, S220, S221, S320, T08, Y427 (vertebral fracture); C412, C795 (bone cancers); C90 (myeloma); D180 (hemangioma).	All expenses incurred on the same day of service were included in healthcare spending estimates.
Inferior vena cava (IVC) filters for the prevention of pulmonary embolism	Reimbursement code: 150263510 ICD10: I260, I269 (pulmonary embolism); I802 (deep vein thrombosis)	Including the healthcare spending of procedures and supplies
Endotoxin apheresis for sepsis	Reimbursement code: 140037250, 140061610	Including the healthcare spending of procedures and supplies
Artificial liver support for acute liver failure	Reimbursement code: 140008410 ICD10: B150, B162, B171, B172, B190, K711, K720, K729 (acute liver failure); B181, B182, B189, K700, K701, K702, K703, K704, K709, K713, K717, K721, K730, K732, K738, K739, K740, K741, K743, K744, K745, K746, K754, K758, K760, K761 (chronic or subacute liver disease)	Including the healthcare spending of procedures and supplies

Pulmonary artery catheterization (PAC) in the intensive care unit (ICU)	Reimbursement code: 160183910, 160075010, 160075170 (pulmonary artery catheterization); Classification number for reimbursement: A300, A301 (ICU): K00x-K91x (surgical procedures) ICD10: I27 (pulmonary hypertension); I319 (cardiac tamponade)	Including the healthcare spending of procedures and supplies
Arthroscopic surgery for knee osteoarthritis	Reimbursement code: 150309510, 150310410, 150311310, 150312410 ICD10: M150, M153, M159, M17, M1909, M1919, M1929, M1999 (osteoarthritis); M224, M942 (chondromalacia); M232, S832 (meniscal tear)	All expenses incurred on the same day of service were included in healthcare spending estimates.
Renal angioplasty	Reimbursement code: 150152010 ICD10: I150 (renovascular hypertension), I701 (renal atherosclerosis); I773 (fibromuscular dysplasia)	All expenses incurred on the same day of service were included in healthcare spending estimates.
Percutaneous coronary intervention (PCI) with angioplasty or stent placement for stable coronary disease	Reimbursement code: 150375110, 150374910, 150375010, 150375410, 150375210, 150375310 (PCI) (the following codes are used for procedures related to acute coronary syndrome: 150374910, 150375010, 150375210, 150375310); 111000570, 112001110, 112006470, 113016270, 113018570, 111000670, 112001210, 112006570, 113016370, 113018670, 111000770, 112001310, 112006670, 113016470, 113018770 (off-hour visit) ICD10: I20-I25 (ischemic heart disease or angina) (I21-I23 for acute myocardial infarction)	All inpatient expenses occurring on the same day of service were included in healthcare spending estimates.
Intravenous anti-herpes drugs for sudden sensorineural hearing loss	Reimbursement code: 620001341, 620003671, 620003746, 620004633, 620006283, 620006284, 620009268, 621144901, 621384302, 621384303, 621384402, 621384411, 621384414, 621384422, 621384424, 621384425, 621660102, 622325900, 640461002 (intravenous acyclovir) ICD10: H912 (sudden sensorineural hearing loss); A60 (herpes simplex infection), B00-B02 (herpes zoster virus infection); B203 (human immunodeficiency virus diseases in herpes virus infections)	a
Surgery for vesicoureteral reflux	Reimbursement code: 150201950, 150326310, 150365410 ICD10: N137, Q627 (vesicoureteral reflux)	All expenses incurred on the same day of service were included in healthcare spending estimates.
Tricyclic antidepressants prescription for children without other psychological disorders	Reimbursement code: 611170035, 611170036, 611170037, 611170647, 611170785, 611170790, 611170791, 611170796, 611170027, 611170028, 620007173, 620006988, 620155801, 611170143, 611170822, 610463147, 611170283, 611170041, 611170042 (oral tricyclic antidepressants) ICD10: F32, F33 (depression); F01-F31, F34-F99 (other psychological disorders)	a
Carotid endarterectomy in asymptomatic patients	Reimbursement code: 150322710 (carotid endarterectomy); 140036710, 140051010, 140051110, 140057810, 140057910, 140058010, 140059310, 140059410, 140060210, 140060310, 140060410, 140059070, 140059170, 140052810, 140058110, 140058210, 140058410, 140058510, 140058610, 140007710, 140008170, 140052570, 140052970, 140007910, 140058770, 140058870, 140033770, 140058970, 140055970, 140029850, 140053670 (dialysis) ICD10: H340-H342 (retinal artery occlusion); G45 (TIA); I60-I63, I66 (stroke); R25, R430-R432, R270, R278, R279, R290, R291, R295, R683, R414, R471, R478, R20 (nervous and musculoskeletal symptoms); I21-I23 (acute myocardial infarction); (J43, J44 (chronic obstructive pulmonary disease); alcohol related disorder (F10); presence of cardiac pacemaker (Z950)	All expenses incurred on the same day of service were included in healthcare spending estimates.
Nasolacrimal probe in infants	Reimbursement code: 150076710 (nasolacrimal probe) ICD10: H043-H046 (inflammation, stenosis, insufficiency, or stricture of lacrimal passages); Q105 (other congenital malformation of lacrimal apparatus)	All expenses incurred on the same day of service were included in healthcare spending estimates.
Electroconvulsive therapy in children	Reimbursement code: 180019910, 180005010 (electroconvulsive therapy) ICD10: F32, F33 (depression)	All expenses incurred on the same day of service were included in healthcare spending estimates.

ICD10: International Classification of Diseases, Tenth Revision.
[a] Including only the healthcare spendings associated with the reimbursement code.

Supplementary Table 4. Change of total number of low-value episodes per 1,000 hospital patients from fiscal year (FY) 2015 to 2019

Definition of low-valuee care	Total number of low-value episodes /1000 patients [a]		Average annual % change [b] (95% confidence interval)	P value
	FY2015	FY2019		
Narrower definition	120.0	111.5	-2.0 (-3.4 to -0.6)	0.02
Broader definition	205.7	203.7	0.6 (-1.6 to 2.8)	0.45

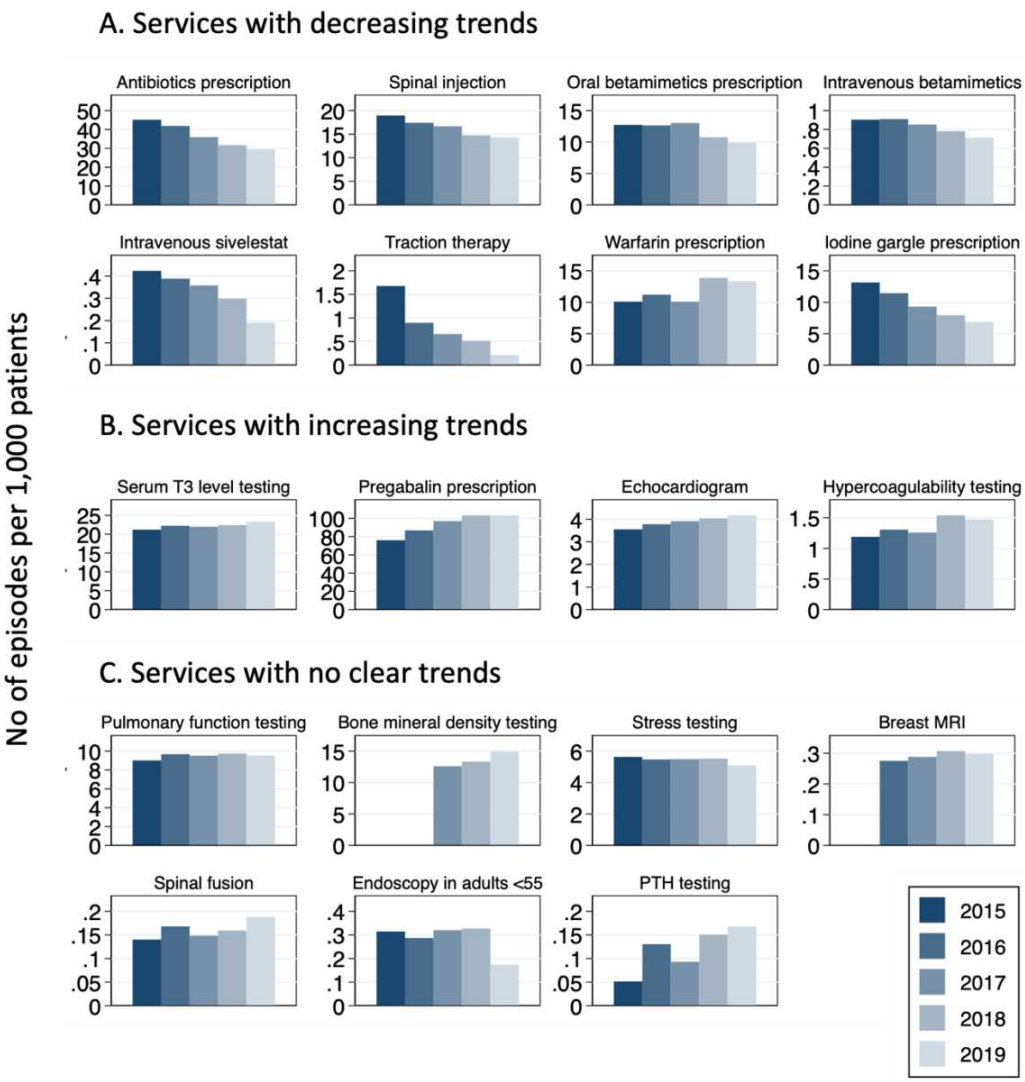
[a] Amontg the 33 identified low-value services, we evaluated the aggregated number of 31 low-value services that were measurable throughout the period, except for bone mineral testing (measurable from FY2017) and breast MRI (measurable from FY2016).
[b] Trends (and p values for trend) are determined by calculating average annual percentage change.

Supplementary Table 5. Change of low-value episodes per 1,000 hospital patients from fiscal year (FY) 2015 to 2019 for 17 healthcare services with most episodes involving low-value care (narrower definition) in FY 2019

Services	Narrower definition				Broader definition			
	No of low-value episodes /1000 patients		Average annual % change [a] (95% confidence interval)	P value	No of low-value episodes /1000 patients		Average annual % change [a] (95% confidence interval)	P value
	FY2015	FY2019			FY2015	FY2019		
Services with decreasing trends								
Antibiotics prescription	37.35	23.61	-11.5 (-13.7 to -9.3)	0.001	45.15	29.41	-10.7 (-12.6 to -8.8)	<0.001
Spinal injection	18.67	14.13	-7.0 (-8.5 to -5.4)	0.001	18.96	14.32	-7.0 (-8.7 to -5.4)	0.001
Oral betamimetics prescription	12.72	9.91	-6.4 (-11.3 to -1.2)	0.03	12.72	9.91	-6.4 (-11.3 to -1.2)	0.03
Intravenous betamimetics	0.90	0.71	-6.0 (-9.6 to -2.3)	0.02	0.90	0.71	-6.0 (-9.6 to -2.3)	0.02
Intravenous sivelestat	0.42	0.19	-16.9 (-28.4 to -3.6)	0.03	0.42	0.19	-16.9 (-28.4 to -3.6)	0.03
Traction therapy	1.05	0.18	-31.6 (-44.0 to -16.4)	0.009	1.68	0.21	-37.3 (-47.6 to -25.1)	0.004
Services with increasing trends								
Serum T3 level testing	21.20	23.33	2.0 (0.6 to 3.4)	0.02	21.20	23.33	2.0 (0.6 to 3.4)	0.02
Pregabalin prescription	12.18	22.90	17.4 (6.3 to 29.7)	0.01	76.08	103.41	8.2 (2.5 to 14.2)	0.02
Echocardiogram	3.53	4.16	4.0 (2.7 to 5.3)	0.002	3.55	4.17	4.0 (2.7 to 5.2)	0.002
Hypercoagulability testing	1.15	1.37	4.9 (2.2 to 7.6)	0.009	1.19	1.47	6.1 (1.7 to 10.6)	0.02
Services with no clear trends								
Pulmonary function testing	8.99	9.51	1.2 (-2.0 to 4.6)	0.31	9.01	9.53	1.2 (-1.9 to 4.5)	0.32
Bone mineral density testing	2.21 [b]	2.95	15.8 (5.7 to 26.7)	0.03	12.59 [a]	14.92	8.9 (-6.0 to 26.0)	0.09
Stress testing	0.58	0.46	-4.9 (-11.6 to 2.4)	0.12	5.63	5.09	-1.9 (-4.5 to 0.8)	0.11
Breast MRI	0.26 [c]	0.28	3.3 (-2.6 to 9.6)	0.14	0.28 [b]	0.30	3.1 (-2.4 to 8.9)	0.14
Spinal fusion	0.13	0.17	5.3 (-6.1 to 18.1)	0.25	0.14	0.19	5.5 (-1.6 to 13.1)	0.09
Endoscopy in adults <55	0.29	0.17	-9.4 (-28.4 to 14.7)	0.28	0.31	0.17	-10.0 (-30.0 to 15.6)	0.27
PTH testing	0.05	0.15	27.7 (0.5 to 62.2)	0.047	0.05	0.17	28.5 (-2.9 to 70.1)	0.07

[a] Trends (and p values for trend) are determined by calculating average annual percentage change.
[b] The estimates for FY2017 were presented because those for FY2015-2016 were unavailable by definition.
[c] The estimates for FY2016 were presented because those for FY2015 were unavailable by definition.

Supplementary Figure 3. Number of low-value episodes per 1,000 patients seeking care, using the broader definition



T3, Triiodothyronine; MRI, magnetic resonance imaging; PTH, parathyroid hormone.

Supplementary Table 6. Crude probability of receiving at least one of the 33 low-value services in the fiscal year 2019 among adult patients, by patient and hospital characteristics

	No. of patients	No. of patients who received at least one low-value service	Crude probability, % (95% CI)
Patients' age (years)			
18–34	28,840	2,027	7.0
35–49	45,473	2,653	5.8
50–64	61,378	2,948	4.8
65–74	68,363	3,448	5.0
≥ 75	88,221	4,225	4.8
Patients' sex			
Female	157,787	9,237	5.9
Male	134,488	6,064	4.5
Charlson's comorbidity score			
0–1	217,858	10,423	4.8
2–4	63,164	3,842	6.1
≥ 5	11,253	1,036	9.2
Size of the treating hospital			
Small (< 200 beds)	28,987	1,790	6.2
Medium (200–499 beds)	163,280	8,601	5.3
Large (≥ 500 beds)	100,008	4,910	4.9

Supplementary Reference

1. Nishikawa A, Yoshinaga E, Nakamura M, *et al.* Validation study of algorithms to identify malignant tumors and serious infections in a Japanese administrative healthcare database. *Annals of Clinical Epidemiology* 2022;**4**:20–31. doi:10.37737/ace.22004