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Expanded Use Of Imaging Technology And The Challenge Of Measuring Value

The benefits of expanded imaging might not be directly related to patients’ disease outcomes.

by Laurence C. Baker, Scott W. Atlas, and Christopher C. Afendulis

ABSTRACT: The availability of computed tomography (CT) and magnetic resonance imaging (MRI) scanning has grown rapidly, but the value of increased availability is not clear. We document the relationship between CT and MRI availability and use, and we consider potentially important sources of benefits. We discuss key questions that need to be addressed if value is to be well understood. In an example we study, expanded imaging may be valuable because it provides quicker access to more precise diagnostic information, although evidence for improved health outcomes is limited. This may be a common situation; thus, a particularly important question is how non-health-outcome benefits of imaging can be quantified. [Health Affairs 27, no. 6 (2008): 1467–1478; 10.1377/hlthaff.27.6.1467]

The availability and use of magnetic resonance imaging (MRI) in the United States has soared since its introduction in the early 1980s. There are now estimated to be more than 7,000 sites offering MRI, collectively performing more than twenty-six million procedures annually. Other forms of imaging have grown as well, with more than 10,000 computed tomography (CT) units estimated to be in operation, and steady increases in the availability of positron emission tomography (PET) and other new imaging modalities.

Acquiring and using advanced imaging availability carries a substantial price tag. New imaging equipment can be expensive—state-of-the-art MRI units can cost $2 million or more—and the costs of facility adaptations and the periodic equipment upgrades and improvements that are often required can also be costly. These high costs raise concerns about whether widespread availability is justified, but they may be worth it if they make possible sufficiently large benefits, such as by improving health outcomes or reducing the use of other more expensive or invasive diagnostic tests. Indeed, in other fields of medicine there is evidence that

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new and expensive technologies can produce benefits that are valued at, or even well above, their costs. On the other hand, there are concerns that the U.S. health care system can also be prone to overuse, particularly of new, high-tech services.

In the case of MRI, CT, and other forms of advanced imaging, evidence about society’s value proposition from expanding availability is sparse. Many studies have examined particular advances, and from them has come evidence that new imaging approaches can often improve things such as the speed and precision of diagnoses. But at the broader level, questions about the costs and benefits of expanding imaging for society and policy encompass a wider set of issues, including the ways in which expanding imaging availability affects the number and type of patients receiving imaging procedures, the types of procedures they get, the impact on their use of alternative diagnostic tests and therapeutic procedures, and ultimately their health outcomes. Although this kind of information has been difficult to develop, there is little question that it is increasingly needed.

In this paper we briefly examine trends in the availability of CT and MRI equipment, and the relationship of increasing availability to patterns of use. We then discuss issues that appear important for efforts to assess the value of expanding imaging availability and illustrate them with an examination of one particular case: the diagnosis of abdominal arterial disease using CT angiography.

Expanding MRI And CT Availability And Use

One source of information about changes in the availability of MRI and CT over time is a set of four “censuses” of MRI and CT sites conducted by the IMV Medical Information Division between 1995 and 2004. These were conducted at four points in time: between August 1994 and August 1995, November 1998 and early 1999, April 2002 and April 2003, and December 2003 and December 2004 (in what follows, we refer to these as the 1995, 1999, 2002, and 2004 surveys). For each site, surveys inquired about a range of items, including the number of MRI and CT units in operation. Although any survey-based approach will miss some facilities and units, results from these surveys are widely used in the industry and have been used in previous publications.

These data suggest dramatic expansions in MRI and CT since 1995 (Exhibit 1). The estimated number of CT units grew more than 50 percent between 1995 and 2004; the estimated number of MRI units more than doubled.

There have also been sizable increases in use. Using Medicare claims data, we counted the total number of procedures performed for traditional Medicare beneficiaries age sixty-five and older, by calendar year, for 1985–2005. We based our calculations on physician-supplier claims, identifying instances in which a physician billed Medicare for the interpretation of the results of an MRI or CT procedure. The number of MRI procedures per 1,000 beneficiaries increased from essentially zero in 1985 to 50 in 1995, and then more than tripled to 173 by 2005 (Exhibit 2). CT procedures also rose dramatically, more than doubling from 1995.
to 2005, when they reached 547 per 1,000 beneficiaries.

There are clear relationships between the availability of imaging units and their use. Using the data on imaging units and the Medicare claims data, we constructed estimates of the number of scanners and procedures by Metropolitan Statistical Area (MSA) for each of the four imaging-site survey years.\textsuperscript{8} Exhibits 3 and 4 plot the changes between 1995 and 2004 in the number of MRI and CT units in 318 MSAs against changes over the same period in the number of procedures provided to traditional Medicare beneficiaries. In both cases, the places that had the largest growth in the number of units also had the largest changes in the number of procedures billed to Medicare. To more formally assess these relationships, we estimated a regression to examine the relationships between changes over time in the number of CT or MRI units in an MSA and changes over time in the number of procedures, controlling for the number of patients in the MSA.\textsuperscript{9} The results suggest that each additional MRI unit is associated with 733 additional MRI procedures among traditional beneficiaries, and each additional CT unit is associated
with 2,224 additional CT procedures (both \( p < 0.01 \)).

Much of this effect is associated with growth in the number of CT or MRI users. When we performed regression analyses relating expansion in availability to changes in the number of beneficiaries who received any CT or MRI procedures, we found that each additional MRI unit is associated with 410 more users of MRI, and each CT unit is associated with about 650 more users of CT (both \( p < 0.01 \)). Expanding MRI and CT availability is also associated with increases in the number of procedures per user, but this relationship does not appear as strong. In regression analyses, adding an additional scanner is associated with 0.002 more MRI scans per user, and also with 0.002 more CT scans per user (both \( p < 0.01 \)).
The association between expanding availability and expanding use suggests potentially important cost impacts. Because Medicare pays for imaging differently depending on where it is performed, and some imaging services are part of hospital stays for which the technical component is paid for through prospective payment, estimates of the net cost of expanding procedure use to Medicare depend on assumptions about where the procedures would be performed. As one guide, we calculated that under the 2005 Medicare fee schedule, the average total amount Medicare would pay for the MRI procedures observed in our data, if billed under the fee schedule, was $713. For CT, the corresponding figure was $308. Based on these figures, an additional MRI unit in a physician’s practice would have been associated with about $550,000 in additional Medicare spending per year, and an additional CT unit would be associated with $685,000.11

**Costs And Benefits**

Whether society ultimately gets its money’s worth for expanding imaging availability is a multifaceted question. At its most basic, the question involves an assessment of the costs associated with expanding imaging and the benefits derived from it. Ideally, this would be done at the level of the population, perhaps conceptualized as a question of the costs and benefits associated with adding new equipment to a geographic area, as they accrue to its population. More formally, the question might be framed as an assessment of the cost-effectiveness of adding new imaging equipment to an area. In principle, by comparing, for the population affected, the net change in imaging and other health care costs associated with adding a piece of equipment to the change in the number of quality-adjusted life-years (QALYs), one could produce an estimate of the cost-effectiveness ratio associated with addition of new equipment.

To begin to make such an assessment, broadly based measures of costs and benefits will be required. To consider sources of costs and benefits, it may be useful to distinguish two groups of patients. First, some patients would not receive any diagnostic testing, imaging or otherwise, if imaging equipment is only sparsely available but would receive testing if availability expands. For example, consider a serious health condition for which there is a conventional test that is invasive and associated with side effects, as well as an imaging test that is noninvasive or associated with less burdensome side effects. If the imaging test is difficult to obtain, some patients for whom the condition is a possibility, but only a remote one, may delay or even entirely forgo testing. But, as imaging equipment becomes more widely available and the test thus becomes more easily obtained, the threshold for referring a patient to be tested may change, and patients who once might not have been tested would receive the imaging test.

In this situation, the costs associated with expanding imaging would include the costs associated with imaging, as well as the impacts on the use of subsequent health care, particularly follow-up tests and procedures. Benefits would be ob-
served if earlier identification of treatable health conditions led to improved outcomes. Moreover, even if disease is not identified, there may be value in the information gained. Being able to rule out a suspected abnormality, for example, can be medically beneficial by improving the direction of further care. It might also have value by eliminating patients’ concern about harboring disease. Although we would expect information of this sort to be generally beneficial for patients, it is worth noting that it need not always be so. For example, the act of sending patients for additional testing can produce anxiety that persists even if patients receive a “negative” result suggesting that the condition of concern is not present.

A second group of patients includes those who would have received some diagnostic testing with less imaging availability but for whom expanded availability leads to different testing patterns. Imaging may substitute for other testing or augment it. For patients in this group, the net costs would include the costs associated with the imaging itself and would incorporate any savings from changes in the use of other tests. Net costs would also include the costs associated with changes in the use of subsequent health care.

Use of advanced imaging for this group could increase the speed with which information is generated and made available. In the absence of advanced imaging, patients and doctors may have had to wait longer for symptoms to develop further or for other types of tests to produce results, to have enough information to make a diagnosis. The precision of diagnosis could also be improved. Many new imaging techniques have higher sensitivity, specificity, and accuracy than older diagnostic approaches.

Quicker and more precise diagnoses would be of clear benefit if they facilitated the use of more effectively targeted treatment approaches or allowed treatment to begin more quickly and thus led to improved outcomes. More precision might also have less tangible benefits, such as by reducing false positive rates and thus reducing patient worry (besides reducing the use of unnecessary follow-up procedures). Substitution of imaging for other tests that carry higher risks of complications or that are more invasive, time-consuming, or uncomfortable than the imaging tests would also produce benefits.

Gathering cost and benefit information to develop a broadly based assessment of the value of expanding imaging seems to us to face two key challenges. The first is moving from the level of effectiveness or cost-effectiveness studies focused on specific clinical situations to analyses that more completely capture the population-level effects. At one level, this need be nothing more than aggregating across cost-effectiveness analyses of each of the possible effects that expanding imaging availability could have on clinical care. There are many studies of the cost-effectiveness of imaging approaches for particular patients with particular conditions, often providing evidence that imaging approaches can be cost-effective.

At another level, though, the scope of the problem becomes daunting. Adding a piece of MRI equipment, for example, may change the use of MRI for patients...
with a range of conditions, not all of which have been studied. Moreover, as imaging availability expands, use may be expected to spread beyond the populations considered in existing studies. Even with sufficient cost-effectiveness evidence, the challenge of combining the evidence across the many effects of availability expansion would remain. Adding a new MRI unit to an area may increase the use of MRI in some circumstances where MRI is clearly cost-effective, but also increase its use in other areas where it is less so, and the net effects will depend on how many and which types of patients fall into each category.

Although challenging, developing population-level evidence is clearly valuable. Expanding our base of cost-effectiveness information could help with efforts to assess the value of expanding imaging, particularly combined with data on how changes in imaging availability affect the ways in which imaging is used. Information could also be gained from analyses that relate the area-level availability of imaging to population-level health spending and outcomes. Although this may only imprecisely link imaging to outcomes of interest, it may be more feasible and thus informative.15

A second key challenge is to more fully address the range of benefits associated with imaging. Although most of imaging’s potential value is related to the information it can provide, this information might not always have direct impacts on the most easily measured health outcomes. Imaging can also improve such things as patient comfort during testing. Existing studies and cost-effectiveness analyses do not typically address these kinds of benefits in a robust way, but to develop an accurate assessment of the ultimate value of expanding imaging, these will need to be considered.

An Example: Diagnosis Of Abdominal Aortic Aneurysm And Related Conditions

- Data analysis. To illustrate these issues, we present an analysis of an emerging, seemingly beneficial, use of CT to diagnose conditions affecting arteries of the abdomen, particularly the abdominal aorta.16 Abdominal aortic aneurysm (AAA) is the development of a weakness in the aorta, one of the body’s most important arteries. If left untreated, it can cause serious health problems and frequently death. Other related conditions that we include are aneurysms, narrowing, or related conditions in other abdominal or pelvic arteries (it being difficult to distinguish diagnostic testing of the abdominal and pelvic arteries in the Medicare claims data). Patients with suspected arterial conditions are candidates for diagnostic testing. In many cases, ultrasound procedures are used to study suspected aortic aneurysms and related conditions, but patients can also undergo other diagnostic testing. For patients who require testing more precise than ultrasound, one option is to use a catheter-based angiogram or aortogram, in which a catheter is threaded into the arteries and used with x-rays to study blood flow patterns. This test is invasive and carries an elevated risk of a range of complications, including potentially life-
threatening embolisms.17 An emerging alternative to catheter angiography is CT angiography (CTA), a noninvasive study using contrast-enhanced CT scanning. The use of CTA began in earnest in the United States in the late 1990s and was well recorded in Medicare claims data by the early 2000s. The risks associated with CTA appear minimal, and CTA appears to be viewed as accurate in the depiction of arterial disease.18

We used the Medicare claims data to track use of abdominal CTA, as well as catheter angiography of the abdominal arteries, in the traditional Medicare population between 2001 and 2005.19 This is the time period during which these procedures are well captured in the claims data, and we computed the number of patients who received these procedures by MSA and year.

There were notable increases over time in the rates of abdominal CTA between 2001 and 2005. In 2001, the national rate was 0.5 per 1,000 Medicare beneficiaries; it grew to 3.9 by 2005. Growth in these procedures is costly for Medicare: in 2005, Medicare paid $565–$743 for a CTA procedure if performed in a physician’s office. At the same time, catheter angiography for abdominal conditions declined slightly, from 8.1 per 1,000 beneficiaries to 7.6.

Expanding use of abdominal CTA could create benefits through a number of channels. First, it could offset the use of more invasive catheter angiography, which has a higher complication rate. To explore this, we used data from 2001–2005 to examine the relationship between expanding CTA use in MSAs and changes in catheter angiography. We estimated a regression in which the dependent variable was the number of beneficiaries in each of 318 MSAs who had received at least one catheter angiography procedure in the given calendar year and the key independent variable was the number receiving CTA, controlling for the number of beneficiaries as well as fixed characteristics of MSAs and annual time trends.20 In this specification, the regression model provides evidence about the ways in which changes over time in the number of CTA users, within an MSA, are associated with changes in the number of catheter angiography users (Exhibit 5). Results suggest that for each 100 additional recipients of CTA procedures, there are 15.4 fewer recipients of catheter angiography ($p < 0.01$). That is, increasing use of CTA is associated with reduced use of catheter angiography, but with a substitution rate that is less than one for one.

These results suggest that many beneficiaries who came to receive CTA were those who previously would not have received either CTA or catheter angiography. Another way to look at this is to examine the relationship between changes in CTA use and changes in the number of beneficiaries who receive either CTA or catheter angiography. We created a regression model in which the dependent variable was the number of beneficiaries who had received either CTA or catheter angiography (Exhibit 5). Here, we observe that an increase of 100 CTA users is associated with an increase of 68.4 users of either of the two ($p < 0.01$). If all new users of CTA were those who would otherwise have used catheter angiography,
this figure would have been zero. As the share of CTA users who would not otherwise have used catheter angiography approached zero, this figure would have approached 100.

From these two results, we can then calculate that for every 100 new abdominal CTA users, about 68 are people who would not have previously received either a CTA or a catheter angiography, about 15 are people who would have received catheter angiography but now receive a CTA instead, and the remaining 16 are those who now receive both CTA and catheter angiography.

Patients switching from catheter angiography to CTA could benefit from the lower complication rate of the less invasive CTA. Patients who newly receive CTA but would not have gotten catheter angiography before could benefit if the additional screening catches disease that would have gone undetected before. To provide some evidence about this, we investigated whether the additional diagnostic testing is associated with changes in therapeutic procedure rates, which are a key mechanism by which improved health outcomes might be expected to come about—if expanded diagnostic imaging catches treatable conditions, we would expect to observe a higher rate of therapeutic procedures. We considered four types of therapeutic procedures: direct repairs for ruptured aneurysms, direct repairs for other than ruptured aneurysms, endovascular repairs, and endarterectomies. Using regression analysis to examine the relationship between expanding CTA rates and treatment rates, we found that for each additional 100 CTA users in an MSA, there are about 1.1 more beneficiaries who receive one or more of these

## Exhibit 5
Responsiveness Of Diagnostic Testing And Therapy Use To Changes In Computed Tomography Angiography (CTA) Use And Other Variables, 2001–2005

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Catheter angiography procedures</th>
<th>CTA or catheter angiography procedures</th>
<th>Therapeutic procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of CTA procedures</td>
<td>$-0.154 (0.04)^{***}$</td>
<td>$0.684 (0.04)^{***}$</td>
<td>$0.011 (0.01)^{**}$</td>
</tr>
<tr>
<td>Number of beneficiaries</td>
<td>$0.011 (0.00)^{***}$</td>
<td>$0.011 (0.00)^{***}$</td>
<td>$0.001 (0.00)^{***}$</td>
</tr>
<tr>
<td>Year 2001 Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Year 2002</td>
<td>$2.93 (2.57)^{**}$</td>
<td>$2.593 (2.51)^{**}$</td>
<td>$0.323 (0.63)$</td>
</tr>
<tr>
<td>Year 2003</td>
<td>$-1.053 (2.64)$</td>
<td>$-1.238 (2.59)$</td>
<td>$-0.807 (0.65)^{**}$</td>
</tr>
<tr>
<td>Year 2004</td>
<td>$-0.066 (2.77)$</td>
<td>$-0.106 (2.71)$</td>
<td>$-0.432 (0.68)$</td>
</tr>
<tr>
<td>Year 2005</td>
<td>$-2.712 (3.00)$</td>
<td>$-2.263 (2.94)$</td>
<td>$-0.975 (0.74)^{***}$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.990</td>
<td>0.993</td>
<td>0.968</td>
</tr>
</tbody>
</table>
treatments (Exhibit 5; \( p = 0.034 \)).

**Lessons from the example.** This admittedly simple investigation does not fully cover all of the issues one might wish to consider in a full-blown investigation of CTA and its use for abdominal artery conditions. Moreover, CTA for these conditions is but one of many uses of CT equipment, and not the most common—depending on the year, only 1 percent or less of all CT procedures done for Medicare beneficiaries are abdominal CTA. We hope that it does, however, convey some of the potential for gaining new information, and some of the analytic and interpretive challenges, that can accompany efforts to better assess the value of imaging diffusion.

Increasing use of CTA in this example is driven by large increases in the use of any advanced screening, and with a much smaller reduction in the use of catheter angiography. There are a few more therapeutic procedures performed when CTA rates increase, but the change is small.

This illustrates the limits of existing cost-effectiveness data in understanding the overall value of expanding imaging availability. Cost-effectiveness data on each of the effects of changing abdominal CTA use—substitution of imaging for catheter angiography for one part, expansion of the population receiving any testing at all for the other—are not available. Even if they were, the rapid expansion in use of the procedure would likely have pushed its use into populations of patients beyond those initially examined in clinical trials. Like many situations in which CT and MRI appear to be used, this is a situation in which tracking costs and benefits at the population level will require broader analyses.

This example also illustrates the challenges associated with measuring benefits. Some progress can be made focusing on measurable health outcomes. Here, the small changes in treatment rates that accompany increasing CTA use do raise the concern that many additional procedures were done for patients with perhaps only small changes in population-level outcomes. However, even small changes in the number of patients receiving treatment could produce important benefits if the benefits to each treated patient are large enough. Formally assessing the impacts on outcomes at the population level would provide valuable information. We also caution that we have not considered the presence of complications from catheter angiography, the potential for more imaging to more precisely identify good candidates for therapy, or the risks to patients from increased radiation exposure.22

More importantly, this example illustrates the potential importance of better assessing and incorporating information about sources of benefits other than health outcomes. In this case, for most of the patients, the main source of benefits would appear to be associated with additional information. Two-thirds of the additional use of CTA is associated with new diagnostic users, and most of these do not go on to therapeutic procedures, but they could receive benefits if they value such things as more quickly receiving information ruling out a potentially serious health condition. These kinds of benefits might, or might not, turn out to be suffi-
ciently valuable to justify the costs of additional procedures, but they certainly should be counted if a full assessment is to be made.

**Concluding Comments**

The diffusion of advanced imaging such as CT and MRI has been rapid and has led to major increases in costs for Medicare and other payers, raising important questions about whether there are benefits sufficient to justify the costs. Analyses that are population-based and incorporate outcomes will be needed to answer these questions.

It seems likely that key benefits of expanded imaging use will in some cases include improvements in measurable health outcomes but will frequently include other, perhaps less tangible, types of benefits. At one level, this raises a set of analytic questions about how these benefits could be measured and incorporated into analyses. At another, it may raise important questions about the extent to which the health care system should pay for benefits other than improvements in objective health measures.

Our focus has been on what we consider to be the most important questions facing an assessment of expanding imaging capacity, but there are other issues that might be addressed in a full analysis. For example, changes in the use of current technologies could affect the development of new services and future knowledge. This may be particularly important as new imaging approaches increasingly contribute to the use of other therapies such as minimally invasive surgery. Manipulating the adoption and use of advanced services today may affect the pace with which new products are developed and brought to market, which could affect the future potential of the health care system.

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**NOTES**

5. One important feature of the MRI and CT markets is that some equipment is located on mobile units that can move from place to place. In our analyses, we attempted to focus on only units that are fixed in a single place.
location. Understanding the empirical implications of this focus is difficult. For MRI, in 2005, there were about 1,200 sites that indicated having a mobile service and having no fixed magnets. The number of magnets being shared among these sites is likely much smaller than 1,200 but cannot be tracked using our data. There are also about 100 magnets that we did count that appear to be fixed magnets at sites that use both fixed and mobile magnets. Among CT sites, there were only about 100 sites that indicated using mobile scanners but not fixed scanners, and about 15 sites with fixed scanners that also indicated using mobile scanners.


8. Beneficiaries are linked to MSAs based on their residence location. We used MSAs rather than Hospital Referral Regions (HRRs) because the imaging survey data associate equipment with counties but not ZIP codes, which are required for HRR construction.

9. The form of this regression was: \( p_{n,t} = b_0 + [b_1 \times n_{t}] + [b_2 \times n_{n}] + ms_{a,i} + Yeart + c_{i,t}, \) where \( p \) is the number of procedures in MSA \( i \) in year \( t \), \( a \) is the number of units, \( n \) is the number of traditional Medicare beneficiaries, \( msa \) a set of fixed effects for MSAs, and \( Yeart \) a set of fixed effects for years.

10. On the 2004 IMV survey, MRI sites averaged about 3,000 procedures per unit per year. CT sites varied depending on their size. Sites with one CT scanner averaged about 4,000 procedures per unit per year, while sites with two or more scanners averaged about 7,000.

11. Recent changes in Medicare payments for imaging in office-based practices have lowered some payments per service, so these amounts would be lower today.


15. The Medicare Payment Advisory Commission makes reference to such an analysis in MedPAC, Report to the Congress: Medicare Payment Policy (Washington: MedPAC, March 2005), 155. It suggests that there is not a strong relationship between overall imaging rates and health outcomes, although it presents no details.

16. We combined abdominal and pelvic procedures because of the existence of many procedure codes, particularly for angiography, that combine abdominal and pelvic artery studies such as studies of the aorta and iliac arteries.


19. We identified the following procedures: CTA of the abdomen or pelvis, including CTA of the abdominal aorta: Current Procedural Terminology (CPT) 72191, 74175, and 75635; and catheter-based aortography or angiography of the abdomen or pelvis: CPT 75625, 75630, 75722, 75724, 75726, 75731, 75732, 75733, 75736.

20. The form of this regression was: \( angio_{n,t} = b_0 + [b_1 \times cta_{n,t}] + [b_2 \times n_{t}] + msa_{i} + Yeart + c_{i,t}, \) where \( angio \) is the number of catheter angiography procedures in MSA \( i \) in year \( t \), \( cta \) is the number of CTA procedures, \( n \) is the number of traditional Medicare beneficiaries, \( msa \) a set of fixed effects for MSAs, and \( Yeart \) a set of fixed effects for years.

21. We identified the following procedures: aneurysm or dissection repairs of abdominal or pelvic arteries (CPT 34800, 34802, 34803, 34804, 34805, 35081, 35082, 35091, 35092, 35102, 35103, 35111, 35112, 35121, 35122, 35131, 35132, 35877), and endarterectomies of the abdominal or pelvic arteries (CPT 35331, 35341, 35361, 35363, 35351, 35355).